National Park Service
U.S. Department of the Interior

Geologic Resources Division
Denver, Colorado

# Antietam National Battlefield, Chesapeake and Ohio Canal National Historical Park, & Harpers Ferry National Historical Park

Geologic Resource Evaluation Report

# Antietam National Battlefield
# Chesapeake and Ohio Canal National Historical Park
# Harpers Ferry National Historical Park
## *Geologic Resource Evaluation*

Geologic Resources Division
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Washington, DC

# Table of Contents

# List of Figures

# Executive Summary

*This report has been developed to accompany the digital geologic maps produced by Geologic Resource Evaluation staff for Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park in Maryland, Virginia, Washington, D.C., and West Virginia. It contains information relevant to resource management and scientific research.*

The story of the three parks featured in this report, Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park is one of the interaction between man and geology. Each park preserves this story in different ways. The experience of the parks begins with the geology, with the processes that established the groundwork from which today's environments, history, and scenery arise. Knowledge of the geologic resources should directly impact resource management decisions regarding potential geological issues, future scientific research projects, interpretive needs, and economic resources associated with each of the considered NPS units.

Geologic processes give rise to rock formations, mountains and valleys, waterfalls and lakes. These processes develop a landscape that welcomes or discourages human use. The geology attracted indigenous peoples and European settlers to the Potomac River valley for hunting, mining, settlement, industrial, and agricultural reasons. Geology inspires wonder in visitors (some 4,100,780 in 2002) to Antietam, Chesapeake & Ohio Canal, and Harpers Ferry, and emphasis of geologic resources should be encouraged to enhance the visitor's experience.

As each park name suggests, historical events within the past 200 years are responsible for their existence. This history is reflected in the buildings, battlefields, bridges, canals, locks, and tow paths found in these parks. Some of the principal geologic issues and concerns pertain to protecting these historic features. Humans have significantly modified the landscape surrounding Antietam, Chesapeake & Ohio Canal, and Harpers Ferry, and consequently have modified its geologic system. This system is dynamic and capable of noticeable change within a human life span. Each park is charged with the task of preserving a snapshot in human history. Geological processes continue to change the landscape, making this charge a challenge.

The following features, issues, and processes were identified as having the most geological importance and the highest level of management significance to the parks:

- Erosion and Slope Processes. The relatively wet climate of the eastern U.S., combined with the steep slopes of the Potomac and Shenandoah River valleys, and the Antietam Creek basin, creates a setting which is especially susceptible to slumping and landslide problems. This is due to a lack of stabilizing plant growth combined with substantial seasonal runoff and frequent occurrence of intense seasonal rainstorms. Runoff can dramatically alter the landscape, creating new hazard areas in the process. Road and trail construction also impacts the stability of a slope.

  Mudstone and shale rich units are typically found in outcrop as slopes. These slopes are prone to fail when water saturated. Large blocks of jointed and faulted sandstone, limestone, and metamorphic rocks are more resistant to erosion and form cliffs. Rockfall and slope failure are potential hazards almost everywhere a cliff face is exposed in the parks.

- Streamflow, Channel Morphology, and Sediment Load. In the wet climate of the eastern U.S., seasonal runoff and intense, short duration, seasonal rainstorms and subsequent flooding impact channel morphology. These seasonal events also result in changes in the load and deposition of sediment in the valleys and along riverways. These changes affect aquatic and riparian ecosystems. Sediment loading can result in changes to channel morphology and the frequency of overbank flooding.

- Mining Issues. Intimately tied with the history of Chesapeake & Ohio Canal and Harpers Ferry is the record of man's quest to extract useful materials from the earth. The history of the town and the canal are linked with the transportation of coal and other raw materials from the west to the east for use in industry. Gold was mined in the area from 1867 through 1940. The abandoned shafts from these mines are a management concern. The canal itself was built from rocks quarried nearby and from the debris left from blasting the channels.

- Historical Landscapes. The parks were all created to preserve a historical context through which the visitor may gain insight into the past. Geology played a significant role in shaping that history especially during the American Civil War. At Antietam National Battlefield, among others, the geology influenced the battle's outcome, with highlands and lowlands determining strategic advantages for both the Union and Confederate armies.

  The geology of the Potomac River valley made canal construction necessary to get over the waterfalls and rapids associated with the "Fall Line." Harpers Ferry was built on the point of rocks jutting out between the Shenandoah and Potomac Rivers. Geology is also involved in compromising the manmade structures and the preserved historical context. Weathering and erosion are relentlessly changing the landscapes of all three parks.

Other geologic parameters and issues such as the paleontological potential of the area, water issues, wetlands, karst- related issues, and general geological and ecosystem concerns, were also identified as critical management issues for Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park and/or Harpers Ferry National Historical Park. These are listed in detail along with recommendations for inventories, monitoring, and research on pages 5- 14.

The rocks present in the Maryland- West Virginia- Virginia area record the ancient beginnings of the Appalachian Mountain belt. The Precambrian gneisses, schists, migmatites, and intrusive igneous rocks exposed in the Blue Ridge physiographic province are more than a billion years old. Over the basement of Precambrian rocks, sand, mud, and carbonates were deposited during the Paleozoic Era.

The entire region was compressed during three separate compressional events, the Taconic, Acadian and Alleghanian orogenies. Associated with each orogeny was metamorphism and igneous activity. After each orogeny, continuing through today, is the processes of weathering and erosion. Runoff, rivers, and streams transport sediment from the highlands to the Atlantic Coastal Plain physiographic province, building the North American continent ever eastward.

Because of the nature of the landscape, several potential geological issues need to be considered with regard to land- use planning and visitor use in the parks. Along with a detailed geologic map and road/trail log, a guidebook that would tie Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park to the other parks in the National Capital Region could enhance a visitor's appreciation of the geologic history and dynamic processes that not only created the landscape but also impacted the historical events showcased at each park. Strategically placed wayside exhibits could help explain the geology to the visitor.

# Introduction

*The following section briefly describes the regional geologic setting and the National Park Service Geologic Resource Evaluation program.*

### Purpose of the Geologic Resource Evaluation Program

Geologic features and processes serve as the foundation of park ecosystems and an understanding of geologic resources yields important information needed for park decision making. The National Park Service (NPS) Natural Resource Challenge, an action plan to advance the management and protection of park resources, has focused efforts to inventory the natural resources of parks. Ultimately, the inventory and monitoring of natural resources will become integral parts of park planning, operation and maintenance, visitor protection, and interpretation. The geologic component is carried out by the Geologic Resource Evaluation (GRE) Program administered by the NPS Geologic Resource Division. The goal of the GRE Program is to provide each of the identified 274 "Natural Area" parks with a digital geologic map, a geologic resource evaluation report, and a geologic bibliography. Each product is a tool to support the stewardship of park resources and is designed to be user friendly to non- geoscientists. In preparing products the GRE team works closely with park staff and partners (e.g., USGS, state geologic surveys, and academics).

The GRE teams hold scoping meetings at parks to review available data on the geology of a particular park and to discuss the specific geologic issues in the park. Park staff are afforded the opportunity to meet with the experts on the geology of their park. Scoping meetings are usually held at each park to expedite the process although some scoping meetings are multipark meetings for an entire Vital Signs Monitoring Network.

Bedrock and surficial geologic maps and information provide the foundation for studies of groundwater, geomorphology, soils, and environmental hazards. Geologic maps describe the underlying physical habitat of many natural systems and are an integral component of the physical inventories called for in Natural Resources Inventory and Monitoring Guideline (NPS-75) and the NPS Strategic Plan.

For additional information regarding the content of this report please refer to the Geologic Resources Division of the National Park Service, located in Denver, Colorado with up- to- date contact information at the following website: http://www.nature.nps.gov/geology/inventory

### Geologic Setting

#### Atlantic Coastal Plain Province:

The Atlantic Coastal Plain physiographic province is primarily flat terrain with elevations ranging from sea level to about 60 m (197 ft). The province was formed by sediments eroding from the Appalachian Highland areas to the west. These sediments were deposited intermittently in a wedge- shaped sequence during periods of higher sea level over the past 100 million years. These deposits were then reworked by fluctuating sea levels and the continual erosive action of waves along the coastline. The Coastal Plain province stretches from the Fall Line east to the Chesapeake Bay and Atlantic Ocean. Coastal Plain surface soils are commonly sandy or sandy- loams that are well drained. Large streams and rivers in the Coastal Plain province including the James, York, and Potomac Rivers are often influenced by tidal fluctuations.

#### Piedmont Plateau Province:

The "Fall Line" or "Fall Zone" marks a transitional zone where the softer, less consolidated sedimentary rock of the Coastal Plain to the east, intersects harder, more resistant metamorphic rock to the west, forming an area of ridges and water falls and rapids. This zone covers over 27 km (17 miles) of the Potomac River from Little Falls, to Seneca, Maryland. This was the obstacle to upriver transportation that the Chesapeake and Ohio Canal was constructed to alleviate. Examples of the manifestation of this transition can be seen in the Potomac Gorge of the Chesapeake and Ohio Canal National Historic Park.The Piedmont Plateau physiographic province encompasses the Fall Line, westward to the Blue Ridge Mountains. (Harris et al., 1997).

The Piedmont Plateau was formed through a combination of folding, faulting, uplift and erosion. These processes resulted in a landscape of eastern gently rolling hills starting at 60 m (197 ft) in elevation which become gradually steeper moving westwards towards the western edge of the province at 300 m (984 ft) above sea level. Soils in the Piedmont Plateau are highly weathered and generally well drained.

#### Blue Ridge Province:

The Blue Ridge Province is located along the eastern edge of the Appalachian Mountains. It contains the highest peaks in the Appalachian Mountain system, mostly in Great Smoky Mountains National Park. Precambrian and Paleozoic igneous and metamorphic rocks were uplifted during several orogenic events to form the steep terrain. Resistant Cambrian age quartzites form Blue Ridge and Short Hill, whereas Precambrian metamorphic rocks underlie the valleys (Nickelsen, 1956).

Eroding streams have caused the narrowing of the northern section of the Blue Ridge Mountains into a thin band of steep ridges, with elevations of approximately 1200 m (3937 ft). The Blue Ridge province is mostly characterized by steep terrain covered by thin, shallow soils, resulting in rapid runoff and low ground water recharge rates.

### Valley and Ridge Province:

The landscape of the Valley and Ridge physiographic province is characterized by long, parallel ridges separated by valleys. These valleys formed where resistant sandstone ridges border carbonate formations. The carbonate was more easily eroded, leaving valleys. Areas dominated by carbonate formations exhibit karst topography. Karst is a term used to describe landscapes dotted by sinkholes, caves and caverns. The Shenandoah Valley forms the eastern portion of the Valley and Ridge province.

Within the National Capital Region, the following parks are all or partially located within the Valley and Ridge physiographic province: Antietam National Battlefield, Catoctin Mountain Park, Chesapeake and Ohio Canal National Historical Park, and Harper's Ferry National Historical Park.

### Antietam National Battlefield

The goal at Antietam National Battlefield is to preserve the scene of the single bloodiest day of the American Civil War. The Battle of Sharpsburg (as it was known by the Confederate Army) began on the morning of September 17, 1862 during General Robert E. Lee's campaign to bring war to the northern states. At the end of a day of intense fighting, more than 23,110 men were dead, wounded, or missing (Antietam National Battlefield, General Management Plan, 1991). This battle led to Lincoln's issuance of the Emancipation Proclamation. The park is among the best preserved Civil War battlefields in the country. Geology played a significant role in the battles marking strategic battle lines and last stands and remains an important resource preservation consideration.

The 3,255 acre park is located in the heart of Maryland surrounded by rolling hills dotted with farms, fields, and pastures reminiscent of the day of the battle. It was established as a National Battlefield on August 30, 1890. It was transferred from the War Department to the National Park Service on August 10, 1933. The boundaries have changed a number of times since becoming a National Park Service unit. The last boundary change was November 10, 1978. This was also the date of the redesignation of the battlefield.

### Chesapeake and Ohio Canal National Historical Park

The historic canal stretches along the Potomac River for 297 km (184.5 miles) of tow path from Washington, D.C. to Cumberland, MD. It has more than 400 km (250 miles) of boundary making it unique in the National Capital Region as the largest and longest. The park's 19,236 acres cut through the four geographic provinces described briefly above. It was George Washington's vision of an industrial corridor along the Potomac River that spurred the canal's construction. From beginning of its construction in 1828 to the end of all operation in 1924, the canal functioned as a transportation route. It was primarily used as a corridor for transporting coal from western Maryland to the port of Georgetown in Washington, D.C.

In 1938, the Federal government acquired the then defunct C&O Canal Company property, focusing on the lowermost 37 km (23 miles) of the canal. near Washington, D.C., for restoration. With the addition of the upper canal, it was established as a National Monument on January 18, 1961 by President Eisenhower. Then, in 1971, under President Nixon, legislation authorized the National Park Service to preserve and interpret the park's historic and scenic features. This designated Chesapeake and Ohio Canal as a National Historical Park. The boundaries of the park last changed on November 10, 1978.

Hundreds of original structures, including 74 lift locks, lock houses, and aqueducts, serve as incredible examples of early civil engineering and of the canal's role as a transportation system during the so- called Canal Era. The canal locks and aqueducts are made of stone quarried along the Potomac River Valley and present a introduction to the rock types of the Appalachian Mountains. The park also supports a great variety of recreational opportunities from the highly urbanized area in Washington, DC to more the rural communities in western Maryland serving 3.1 million visitors in 2000.

### Harpers Ferry National Historical Park

The small town of Harpers Ferry and the National Historical Park associated with it are located at the confluence of the Shenandoah and Potomac Rivers in the states of West Virginia, Virginia, and Maryland. Harpers Ferry played a strategic role in the Civil War changing hands 8 times. It was designated a National Monument on June 30, 1944, and redesignated on May 29, 1963, as a National Historical Park. The boundaries of Harpers Ferry last changed October 6, 1989. The 2,287-acre park is within the Blue Ridge physiographic province and contains forested mountains, riparian habitats, and floodplains that surround the park's historic town area.

# Geologic Issues

*A Geologic Resource Evaluation scoping session was held for National Park Service Units in the National Capital Region from April 30- May 2, 2001, to discuss geologic resources, to address the status of geologic mapping, and to assess resource management issues and needs. The following section synthesizes the scoping results as they apply to Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park, in particular, those issues that may require attention from resource managers are addressed.*

### Erosion and Slope Processes

The topographic relief in the areas around Harpers Ferry, Antietam, and along the Chesapeake & Ohio Canal can be quite high. In areas such as above Harpers Ferry, near Burnside Bridge at Antietam, and near Great Falls the likelihood of landslides increases with precipitation and undercutting. Using a topographic map and a geologic map in conjunction with rainfall information could provide some warning for high risk areas.

The intense erosion of steep slopes is responsible for the stunning vistas of the Potomac and Shenandoah Rivers. However, these erosional processes are also the cause of an important geological resource management issue: mass wasting and rock falls.

The walls of many of the river and tributary valleys at Antietam, Harpers Ferry, and Chesapeake & Ohio Canal are steep slopes (Figures 3 and 4). This renders them highly dangerous because of the likelihood of rock falls, landslides, slumps, and slope creep. Stronger rock units such as sandstones and metamorphic rocks are highly fractured creating potential rock fall hazard zones. Landslides, slumps, and slope creep are major concerns in the weaker rock units such as shales and mudstones.

Similarly, slumps and other forms of slope failure are common for units that are not necessarily associated with cliffs. Unconsolidated alluvial deposits for instance, are especially vulnerable to failure when exposed on a slope. A heavy rainstorm, common in the eastern climate, can cause serious damage to valley slopes, many of which, due to development lack stabilizing plant and tree roots. The rock and soil, suddenly saturated with water, can slip down slope causing a huge slump, mudslide, or mudflow.

Many trails in the parks lead visitors through spectacular river and forest scenery; however, these trails are at extreme risk for rock fall and landslides. In less visited areas of the parks, slope processes are also creating an impact.

Flooding of the Potomac and Shenandoah Rivers has a profound impact on the riverbanks and the cultural and geological resources found there. They are an all-encompassing threat to park natural, cultural and recreational resources, to park operations and budget for extended periods of time. Many structures and trails along the Shenandoah at Harpers Ferry are being damaged or destroyed by seasonal flooding.

Erosion and culvert management are major issues, but have received little management attention. An inventory of the parks' culverts, many of which are classified structures because of the historical character of the parks, is needed. An inventory should include the impacts of culvert outflows as well as the condition of the culverts themselves.

#### Inventory, Monitoring, and/or Research Needs

- Use shallow (10- inch) and deeper core data to monitor rates of sediment accumulation and erosion in local streams, and analyze changes in chemical constituents of sediments.
- Use repeat LIDAR measurements to document changes in shoreline location and elevation along the Potomac River. Document changes immediately after storms, which generally have impacts that greatly exceed continuous processes operating in non- storm conditions.
- Monitor steep slopes for rock movement and manage undercut areas appropriately at Harpers Ferry.
- Study potential relation between shoreline change and development, particularly engineering works designed to limit erosion.
- Monitor hazards to staff and visitors from unstable slopes and rockfalls.
- Monitor changes to unstable engineered sites and to geologically active areas such as the Potomac Gorge, where visitors or park infrastructure such as trails may be at risk.
- Document locations of swelling clays and assess impacts to park infrastructure.
- Monitor erosion rates by establishing key sites for repeat profile measurements to document rates of erosion or deposition, and reoccupy if possible shortly

after major storm events. Repeat photography may be a useful tool.

- Measure the development of stream deltas as surrogates for erosion and sedimentation within an entire watershed.

- Perform a comprehensive study of the erosion and weathering processes active at the parks, taking into account the different rock formations versus slope aspects, location and likelihood of instability.

- Create a rockfall susceptibility map using rock unit versus slope aspect in a GIS; use the map in determining future developments, siting of facilities. and current resource management including trails, buildings, and recreational use areas.

- Inventory and monitor debris flow potential near picnic areas, relate to slope and loose rock deposits.

- Inventory runoff flood susceptible areas, relate to climate and confluence areas.

- Perform trail stability studies and determine which trails are most at risk and in need of further stabilization.

- Further research causes of landslides and slumping to help predict future events.

### Stream Flow, Channel Morphology, and Sediment Load

The rivers and streams greatly define the landscape at Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park. Understanding the seasonal variations of stream flow and the sediment contained in stream beds is necessary to understand the ever evolving ecosystems along the waterways. Channel morphology changes, especially during flooding, affect cultural as well as geological resources by threatening the stability of stream banks, creating potential for collapse. Intense events may also result in periodic deposits of deep sediments.

Sediment load is an indicator of the level of erosion upstream. With development and increasing deforestation, sediment load increases continually. Sediment loads and distribution affect aquatic and riparian ecosystems. Because sediment loading can result in changes to channel morphology, overbank flooding frequency may also be affected.

#### Inventory, Monitoring, and/or Research Needs

- Correlate changes in stream morphology and sediment flux with impacts of external development such as removal of vegetation and increases in impervious surfaces.

- Measure long- term and storm- derived changes in shorelines, using multispectral aerial photos, lidar, and stream gauging.

- Measure and monitor streamflow, including seasonal mean flows, lowest flow rates, and timing and magnitude of storm events. With this information, develop comparative data between tributaries affected by varying degrees of development, and contrast with reference streams where watersheds are dominantly or entirely within protected land if available.

- Measure changes in development in park tributary watersheds. Incorporate detailed data from appropriate county maps into a GIS database, focusing on changes in impervious surfaces, road crossings, buffering vegetation, and stormwater management systems.

- Measure morphologic change in stream channels. Reliable measurements generally require 3- 5 cross sections over several hundred meters of channel.

- Monitor stream flow, including seasonal mean flows, lowest flow rates, and timing and magnitude of storm events. Supplement data from fixed river- level gauges with field data on submergence and exposure of key sites that can be correlated with ecosystem response to floods and droughts.

- Determine sedimentation rates and sediment composition, including contributions of litter and pollution from surrounding developed areas. Establish sites for repeat stream profile measurements, and obtain measurements shortly after major runoff events, if possible.

- Study the sediment influx for small basins in the parks.

- Inventory current channel morphological characteristics.

- Conduct hydrologic condition assessment to identify actual and potential "problem reaches" for prioritized monitoring. Once "problem reaches" are identified, monitor with repeat aerial photographs.

- Research effects of land use and climatic variation on streamflow.

- Investigate paleoflood hydrology.

- Conduct research of ungaged stream sediment storage and load.

- Measure sediment load on streams of high interest for comparative assessment. Data will provide information for making management decisions.

#### Mining Issues

Abandoned mines pose a serious potential threat to any ecosystem. Especially in wet costal environments, surface water in steams, surface runoff, and groundwater can be contaminated with high concentrations of heavy metals leached from mine tailings. Heavy metals may also contaminate soils which in turn can impact plant and animal life that live on the soil. Abandoned mines are hazards for visitors and can alter hydrogeologic test results.

In Chesapeake & Ohio Canal National Historical Park, there are four quarries, and three mines. Limestone, marble, and the Seneca sandstone were quarried for use in constructing the canal before 1828. Gold mining was a focus in the Great Falls area from 1867 until about 1940. Three closed mining shafts, located near the present intersection of Falls Road and MacArthur Boulevard, are part of the Maryland Mine. The first shaft, 100 feet deep, was sunk in 1867, the second, 135 feet deep was completed in 1891, and the last was sunk to 135 feet in 1906. The Maryland Mine was shut done in 1908 and reopened by Atlantic Development Company in 1913 and closed again in 1921. There was some development work on the 135- foot and 200- foot levels between 1936 and 1939. The mine closed permanently in 1940 (Goetz, 1979). Another mine, the Ford Mine, contains several adits which were closed with concrete by the National Park Service. Together with the Maryland Mine, they makes up the system known as the Great Falls gold mines. The Ford Mine collapsed in 1890. The shafts associated with the Maryland Mine are plugged and have a fence around the backfilled openings (Ingram and Stover 1998).

Stone material, including gray and red Seneca Sandstone, Frederick limestone breccia, Potomac breccia, calico marble, and Potomac marble, have been used for many national landmarks. These include the Smithsonian Castle, the White House and the Capitol building, quarried from the Seneca Mill, near Seneca, Maryland, a marble quarry from White's Ferry, Maryland, and the marble quarries near Dickerson, Maryland (Ingram and Stover, 1998).

Limestone for cement used in the masonry structures of the canal was mined along the Chesapeake & Ohio Canal on Round Top Hill, near Hancock, Maryland. The Roundtop mine has seven openings (an eighth opening is natural) with over 1,400 feet of workings (Goetz, 1979). The largest of the seven is 150m (500 ft) deep and with stopes 6 to 15 m (20 to 50 ft) high. Three of the openings for this mine system lie within the boundaries of Chesapeake & Ohio Canal National Historical Park (Ingram and Stover 1998). They were closed in with bat gates in 1994. The other four are across the rails- to- trails hiking/biking path on Maryland state lands.

The Allegheny Plateau is host to workable bituminous coal measures of Maryland, specifically in Allegany and Garrett Counties. The southern end of the easternmost deposits are in the Upper Potomac basin. The basin is drained by the North Branch of the Potomac River. Coal mining exposes iron sulfides to oxygen producing sulfuric acid. In addition to lowering the pH and accelerating the chemical weathering potential of the water, Maryland streams downstream of the coal mining areas contain elevated levels of dissolved solids, including iron, manganese, and aluminum (Hollyday and McKenzie, 1973).

Inventory, Monitoring, and/or Research Needs

- Conduct periodic water (surface and groundwater) and soil sampling and testing to detect and monitor heavy metals. Drinking water is especially important to monitor.
- Research the mineralogy and chemistry of ore deposits throughout the park including descriptions, mineral content, and locations of where the ore-bearing strata and ore shoots crop out and are accessible to the public, and where they may impact flora and fauna.
- Complete inventory of the ore content in the recent unconsolidated deposits and soils.
- For resource management issues and questions, contact the Abandoned Mineral Lands (AML) staff at the Geologic Resources Division office, Denver, CO.

#### Historical Landscapes

The overall goal of the Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park is to maintain the landscapes as they were at the time of the specific events which led to park formation. Preservation efforts encompass both natural and cultural resources. This goal is threatened by the continuous natural processes of erosion and weathering and the demands of increasing local population and urban development (Figures 1 and 2). Conflicts also arise from opposing values between cultural and natural resource management. For example a historic leasing program may issue a historic lease to provide an avenue for restoration of a historic building that may propose removing surrounding natural resources or planting exotics.

Along the Potomac River there are a number of overlapping leases, rights- of- way, and easements. The Potomac Interceptor sewer line, telecommunications lines and towers, utility crossings, power plants, roads and highways, railroads, etc. are all competing for space and access to the river corridor.

Inventory, Monitoring, and/or Research Needs

- Map new development and changing land use, including construction, deforestation, other land cover changes, and paving of previously vegetated surfaces.
- Revisit sites of 1950s- 1960s studies of pre-urbanization streams to assess differences from

present conditions and thus establish initial data points to assess rates of change driven by development stressors.

- Create an enhanced topographic map base for Antietam National Battlefield.

- Update resource management for any newly acquired lands.

- Monitor human impacts on camping and climbing areas, such as: official and social trails, fishing sites, etc. along Chesapeake & Ohio Canal.

- Use sediment coring, tree ring studies, and historical data to develop chronologies of past floods and their impacts, then document future frequency and extent of flood impacts, including changes to shoreline morphology and position, nature of the substrate, post- flood changes, and ecosystem recovery. Where possible, data should also be collected during storm and flood events to monitor immediate effects.

- Assess the environmental impacts of any proposed construction sites near park boundaries via photo points or aerial photography.

- Locate quarries in relationship to locks and other stone historic structures along Chesapeake & Ohio Canal.

### Paleontologic Potential

The river and valley landscape at Antietam, Harpers Ferry, and Chesapeake & Ohio Canal contains more than just a collection of cultural resources and relics, it contains a record of prolific ancient life. Fossils at the parks record some of the earliest forms of life and include several types of Paleozoic and Mesozoic age algae, corals, and brachiopods mollusks, and other lifeforms. These preserved specimens should be protected and catalogued for scientific study, future generations, and increased visitor appreciation of the parks.

Inventory, Monitoring, and/or Research Needs

- Perform a comprehensive study of the paleontologic resources at the parks.

- Compile an inventory of all paleontologic specimens present in the parks.

- Attempt to determine the locations of paleontologic specimens removed from the parks that are now in private collections to obtain an accurate inventory.

- Draw visitor attention to the fossil resources at the parks with graphics, brochures and exhibits.

### Water Issues

In the moist eastern climate of Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park, water is present in streams, rivers, runoff, springs and groundwater wells. Water resources are threatened by contamination and overuse in the urban and agricultural settings of these park units. The most severe threats to park hydrology are presented by existing and future development in the rapidly growing region.

Maintaining an agricultural setting at Antietam creates a situation in which runoff from fields both within the park and in neighboring farms in the Antietam Creek watershed can potentially contaminate both the surface water and groundwater systems including springs. Knowledge of the chemicals used in regional agriculture and an understanding of the hydrogeologic system, including groundwater flow patterns are essential to protect the park's ecosystem. In addition to agricultural runoff, industrial, sewer, street and commercial runoff are also potential sources of water contamination at Antietam.

The movement of nutrients and contaminants through the ecosystem can be modeled by monitoring the composition of system inputs, such as rainfall, and outputs, such as streamflow. Other input sources include wind, surface runoff, groundwater transport, mine drainage, sewage outfalls, landfills, and fill dirt. The parks need to monitor their own water sources for discharge and contaminant levels as records from other agencies become confused. For instance at the USGS gauging station #01619500, downstream of Burnside Bridge at Antietam, files indicate several agencies were collecting various data at various levels of accuracy and clarity. Consistency is crucial to establishing baselines for comparison.

The Potomac and Shenandoah watersheds cover enormous areas. Tributaries from a series of small watersheds enter the Potomac River along the Chesapeake & Ohio Canal. Most of these are ungaged.

Monitoring water quality and discharge has largely been left up to other agencies while the staff at Chesapeake & Ohio Canal monitors drinking water wells and groundwater contamination sites.

Streams in effect integrate the surface runoff and groundwater flow of their watersheds. In doing so they provide a cumulative measure of the status of the watershed's hydrologic system. The park generally manages only the last few hundred meters of any tributary streams. This means resource management has little control over water quality, quantity, or sediment load within any tributary streams. Erosion and aggradation data for streams in all three parks are scarce. Increased interagency cooperation could establish better water data controls.

Urban development surrounding the three parks affects the watershed in a variety of ways not related to water contamination. The hydrogeologic system changes in response to increased surface runoff. This increase is a result of the further development of impervious surfaces such as parking lots, roads and buildings. Sedimentation also increases due to land clearing for development. Water temperatures increase because of the insulating nature of impervious surfaces. Runoff from a parking lot on a hot July day is at a much higher temperature than from a grassy slope.

#### Inventory, Monitoring, and/or Research Needs

- Monitor ground and surface water quality and determine their impacts on the agricultural landscape at all three park units (relevant to preserving the historic landscape at Antietam National Battlefield).
- Monitor nitrates, phosphates and herbicides in surface water to determine if forests serve as effective buffers of contamination at Antietam.
- Monitor discharge at Mumma and other springs at Antietam to establish a baseline. Also determine baselines for biological and chemical parameters for regional springs.
- Continue to encourage educational programs such as "Water Watchers" (for high schools, started in 1995 at Antietam National Battlefield), which collects water quality data.
- Identify point and non- point pollution sources for wetlands and tributaries of the Potomac and Shenandoah Rivers in the Harpers Ferry vicinity.
- Develop a monitoring program for water quality with an emphasis on protection and restoration projects at Harpers Ferry.
- Obtain digital coverages for existing data on springs, map new spring locations for Harpers Ferry National Historical Park.
- Monitor the long- term impacts of flooding on resources at Chesapeake & Ohio Canal.
- Map and quantify subterranean water recharge zones at Chesapeake & Ohio Canal.
- Install monitoring stations to measure atmospheric inputs of important chemical components (such as nitrogen, mercury, and pH), and outputs to streams and groundwater, including karst waters at Chesapeake & Ohio Canal National Historical Park.
- Expand detailed mapping showing changes in elevation since the $19^{th}$ century at Chesapeake & Ohio Canal.

### Wetlands

The dynamic nature of wetland environments makes them an indicator of the overall status of the ecosystem. Many sites have yet to be identified and/or evaluated. The first step toward an inventory would be to validate the classification of the Fish and Wildlife Service and refine the delineation according to their guidelines. Once sites are identified and compared with past photographs and records, monitoring trends becomes possible. Parameters include water chemistry, sediment influx and vascular plant characteristics.

#### Inventory, Monitoring, and/or Research Needs

- Study the effects of fire/drought on wetlands and slope stability.
- Identify and characterize wetland areas at Chesapeake & Ohio Canal. Monitor wetlands at Harpers Ferry National Historical Park.

### Karst Related Issues

The rocks present at Antietam, Chesapeake & Ohio Canal and Harpers Ferry include limestone, marble and other carbonate- rich rocks. Carbonate rocks are susceptible to dissolution both from surface water and groundwater. Air pollution over the eastern United States has caused the acidity of rainwater to increase, speeding the dissolution of carbonate rocks.

Many of the caves along the Potomac River corridor are a result of carbonate dissolution. Karst, a term that describes the features produced by dissolution of carbonate rocks including fissures, sinkholes, underground streams, and caverns, is a present concern at all three parks. Unknown sinkholes and caverns can pose a threat to visitor safety and park infrastructure. The presence of a karstic underground passageway can profoundly affect the hydrogeologic groundwater system.

#### Inventory, Monitoring, and/or Research Needs

- Map surface and subsurface karst features (including caves) at Antietam National Battlefield and Chesapeake & Ohio Canal National Historical Park.
- Complete basic cave inventory for Harpers Ferry National Historical Park including John Brown Cave.
- Perform an exhaustive mapping study of specific cave areas in the parks to allow for the preservation and protection of these resources.
- Monitor important springs and caves at Harpers Ferry for water quality and the presence of rare aquatic invertebrates.

### General Geology and Ecosystem Concerns

Inventory, Monitoring, and/or Research Needs

- Assess geochemical inputs from external sources, including wind, surface runoff, groundwater transport, mine drainage, sewage outfalls, landfills, and fill dirt for impacts on bedrock, soil, and water chemistry.
- Collect and analyze core samples of soils, sediments, and bedrock to assess storage and buffering of chemical components (establish a baseline), and monitor any chemical changes, including the introduction of contaminants.
- Link to the USGS Minerals Program's geochemical landscapes project to provide a regional context for the parks.
- Distribute scientific terminology in layman's terms to park staff for use with public.
- Develop visitor use maps, publications, guided walks, and programs interpreting geology as a significant resource in the parks.
- Correlate geology (surficial and bedrock) with vegetation to predict location of plant types, distribution, etc..
- Identify bedrock of differing geochemical characteristics, and correlate with variations in assemblages and species richness of ecosystem components such as vegetation and aquatic species.
- Establish monitoring stations at the same sites used for vegetation and aquatic monitoring to assess the interaction of chemical inputs with ecosystems in various geochemical environments, and the varying resilience of those environments when subjected to a range of chemical stressors.


**Figure 1: High water damage at Antietam National Battlefield. Erosion from flooding along Antietam Creek disrupts visitor trail access and causes resource management concerns about the protection of Burnside Bridge at Antietam National Battlefield. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

**Figure 2: Historic structure losing ground to Shenandoah River. One of many examples of historic structures and features in danger of being washed downstream by the Potomac and Shenandoah Rivers at Harpers Ferry National Historical Park. Periodic, seasonal floods cause severe river bank damage and change channel morphology. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

**Figure 3: Slope processes at Harpers Ferry. Slope creep and erosional undercutting have undermined this private stairway above Harpers Ferry National Historical Park. Such processes have the potential to destroy trails along slopes and bury features below. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

**Figure 4: Slopes along Antietam Creek. Periodic floods, and slope processes create trail management issues at Antietam National Battlefield. Frequent trail closures and maintenance occur due to slumping and high water. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

# Geologic Features and Processes

*This section provides descriptions of the most prominent and distinctive geologic features and processes in Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park*

### Antietam National Battlefield

#### 1860 Landscape

The General Management Plan calls for maintenance of the historical landscape at Antietam National Battlefield. The landscape present in 1860 included forest, orchard, and agricultural fields and farms. Maintaining this landscape often means resisting natural geologic changes, which presents several management challenges.

Geologic slope processes such as landsliding, slumping, block sliding and slope creep are constantly changing the landscape at Antietam. Runoff erodes sediments from the open fields and carries them via tributaries to Antietam Creek, Sharpsburg Creek and Mumma Run. This can impact historical features such as Bloody Lane and Burnside Bridge, numerous farmsteads and other structures. Erosion naturally diminishes higher areas and fills in the lower areas altering the historical context of the battlefield (Figures 5 and 6).

#### Karst Landscape and Processes

The carbonate rock units present at Antietam National Battlefield include the Chambersburg Limestone, New Market Limestone, Pinesburg Station Dolomite, Rockdale Run Formation, Stonehenge Limestone, Tomstown Formation, among others. The dissolution of carbonate rocks by groundwater through fissures, cracks, or joints creates karst features. Karst features can include underground streams, springs, caves, sinkholes, and pinnacles. The karst features around Antietam National Battlefield have not yet been inventoried.

The processes involved in creating a karst landscape include dissolution, sinkhole collapse, and the formation of caverns. Sinkholes are developed throughout most of the formations of carbonate rock in the area but are more concentrated in the Elbrook and Conococheague formations, Stonehenge Limestone, Rockdale Run Formation, and the Chambersburg Limestone. The presence of karst has had a dramatic effect on the hydrogeology of the area. Since the Antietam Creek basin is underlain almost entirely by folded and faulted carbonate rocks of lower Paleozoic age, its hydrogeologic regime is potentially altered by the dissolution of the carbonate below.

The groundwater discharge of the basin is about 85 percent of the total. This is higher than surrounding areas not underlain by carbonate rocks, but instead by Cambrian and Precambrian metamorphic rocks. Large quantities of groundwater are stored in the soil and substrate. The aquifers in the area are among the most productive in the state of Maryland. This groundwater comes in large part from streams that flow off the mountains directly into sinkholes. Many streams lose most of their flow within a mile of reaching the carbonate rocks in the valley. The low density of perennial streams in the Antietam Creek basin is a result of subsurface drainage through solution cavities along fractures, faults, joints and sedimentary bedding in the carbonate rich rock units (Nutter, 1974).

Karst landforms, like sinkholes and caves, occur elsewhere in the area including in the Great Valley, the Valley and Ridge, and the Frederick Valley, Culpeper basin, and Westminster terrane in the western Piedmont province. These areas have abundant limestone, dolomite, and marble rock units (Southworth et al., 2001). Karst is rare in the Blue Ridge province because marble occurs only as small bodies. Karst occurs in three different sections of the Piedmont physiographic province. Kanawha Spring, just east of Point of Rocks, flows from the limestone of the Frederick Formation which underlies the flood plain. Limestone cobbles within the conglomerate of the Leesburg Member of the Balls Bluff Siltstone dissolve forming hummocky topography with abundant sinkholes and springs just southeast of Point of Rocks. In addition, marble and limestone rock units of the Westminster terrane (exposed along Monocacy River north of Indian Flats) underlie linear valleys. These form abundant sinkholes to the north.

### Chesapeake & Ohio Canal National Historical Park

#### Canal

The Chesapeake & Ohio Canal runs along the length of the Potomac for some 297 km (184.5 miles) from Washington, D.C., to Cumberland Maryland. It was built to provide a viable means of transportation over the so-called "Fall Line," an area of waterfalls along the major rivers above the crystalline bedrock of the Piedmont physiographic province. Development and westward expansion demanded a way to reach the Ohio River valley and beyond. Originally the canal was planned to extend from Georgetown to Pittsburg, Pennsylvania by way of the Potomac, Youghiogheny, and Monogahela valleys with a summit tunnel over 6 km (4 miles) long (Davies, 1977).

Along the canal's length are numerous locks, aqueducts, lock houses, channels, and tow paths. These historical features do more than preserve examples of early civil engineering; they present the rock formations and geologic structures of the Potomac River corridor in miniature. The canal is unique in that it is the only unit within the National Park system that crosses 3 physiographic provinces along a major river. Along its entire length the canal provides an opportunity to examine the geologic history of the central Appalachian region and the canals contribution to development of the area (Southworth et al., 2001).

Sandstones, limestones, dolomites and metamorphic and igneous rocks were quarried along the river for the construction of the canal. When viewing a large rock wall, lining a canal lock, a visitor can see a variety of geologic features: fossils, crossbeds, burrows and other bioturbation, oolites, gneisses, granites, and soft sediment deformation features (Figure 7). In effect, the canal itself is a geologic classroom along its length (Davies, 1989).

There are caves along the Chesapeake & Ohio Canal as well. Some of these features have emergent springs. The canal, running along side the river also provides a riparian zone of protection to the Potomac as human development increases on the park boundary and on the opposite side of river (Figure 8).

#### Potomac Gorge

(Note:  The Potomac River itself is not in the park. It falls under the jurisdiction of the state of Maryland. The Chesapeake & Ohio Canal boundary only goes to the high water line on the river banks).

"Because of its unusual hydrogeology, the Gorge is one of the country's most biologically diverse areas, serving as a meeting place for northern and southern species, midwestern and eastern species, and montane and coastal species. The site contains more than 400 occurrences of 200 rare plant species and communities; a major river system with numerous tributaries; noteworthy stands of upland forest; many seeps and springs harboring rare groundwater fauna; and abundant wetlands of various types." (Allen and Flack, 2001).

The gorge occupies the transition zone between the crystalline rocks of the Piedmont physiographic province and the sediments of the Atlantic Coastal Plain province. During the approximately 5 million years of erosion that produced the gorge, the Potomac River has cut at least 6 different terraces. These are remnants of former flood plains and are included in the Quaternary age terrace deposits unit. Downcutting into these terraces by the Potomac River has created islands, pinnacles, shoestring channels, waterfalls, rapids, oxbows, plunge pools, and potholes (Southworth, Fingeret, and Weik, 2000). These provide a variety of habitats that host the gorge's rich ecosystem.

Periodically large floods, such as in 1936, 1942, 1972, and 1996, scour the gorge, impact park infrastructure, and deposit sediments and massive amounts of debris within and along the canal. Floods are major contributors to erosion and can dramatically alter the river channel's morphology. This has profound effects on the riparian ecosystem present in Chesapeake & Ohio National Historical Park including changing the habitat for the flora and fauna growing along the river.

### Harpers Ferry National Historical Park

#### John Brown Cave

John Brown is famous at Harpers Ferry for the uprising he instigated in 1859, attempting to steal weapons from the Federal armory. A cave in the park now bears his name. The cave is located near the B&O underpass. This cave is approximately 1219 m (4,000 ft) long and formed in the carbonate unit of the Tomstown Formation. Here the unit is highly deformed as part of the eastern limb of a large syncline centered in the overlying Waynesboro Formation to the west (Patchen and Avary, 1986).

#### 1800's Landscape

Harpers Ferry was built at the confluence of the Potomac and Shenandoah Rivers (Figure 9). During the town's heyday, it was an important intersection of river, railroad, and canal transportation routes. A host of historical figures including George Washington, Thomas Jefferson, Meriwether Lewis, John Brown, Abraham Lincoln, "Stonewall" Jackson, Frederick Douglass, and George Armstrong Custer all left their mark on the history of Harpers Ferry.

One of the major goals of the park is to preserve the state of the town around the time of the Civil War, including preserving and restoring the historic buildings in the town and the landscape around it. The geology encompasses the town itself and is reflected in the building stone, carved steps and walkways, and historic industries. Hand- carved steps are within the Harpers Formation. Robert Harper's house and St. Johns Episcopal Church (1852) were built of Harpers Phyllite. Nearby, St. Peters Roman Catholic Church was constructed using Weverton Quartzite (Patchen and Avary, 1986). Like at Antietam National Battlefield and Chesapeake & Ohio Canal National Historical Park, the continuous geologic processes of erosion, deposition, landsliding, slumping, creeping, rock fall, flooding, and chemical weathering present serious challenges to the preservation of a snapshot in time.

Among the rock units underlying the town, forming the foundation for many of the town's structures, and forming the precipitous slopes above are the exposed shales, phyllites, sandstones, greenstones, dolomites, and limestones of the Harpers, Tomstown, Antietam, Weverton, Loudoun, Catoctin, and Swift Run Formations. Shale predominates on the eastern side of the park while limestone is mainly present on the western side. Numerous trails run along the sides of the hills above the town, showcasing the Paleozoic and Precambrian rock units of the Blue Ridge physiographic province.

### Blue Ridge Anticlinorium

The Blue Ridge Anticlinorium is a late Permian age structure which underlies the Harpers Ferry area. It extends from southern Pennsylvania into Virginia (Nickelsen, 1956). The anticlinorium is asymmetrical, the western limb is steeper than the eastern limb. It is on the western overturned limb of the anticlinorium that the excellent exposures of the Harpers Formation, a thick sequence of mostly fine- grained metamorphosed clastic rocks, show multiple episodes of folding and are fundamental in determining the tectonic setting of the Alleghanian orogeny.

The Harpers Formation shows folding, refolded folds, and several generations of cleavage. Without these features, the urbanization of the area could have taken a much different turn. The landforms created by the anticlinorium made it necessary to construct canals, bridges, and a tunnel. In addition to this, fractures and the high degree of dip of the rock beds on the limbs of the folds allowed for the development of numerous local slate quarries (Patchen and Avary, 1986; Onasch et al., 1987).

### Wetlands and Riparian Environments

Approximately 100 acres of wetland area fall within the park boundaries. Most of this area is along the banks of the Shenandoah River just west of the town of Harpers Ferry. Wetlands are an important resource because they are particularly susceptible and vulnerable to environmental change. Wetlands exhibit rapid responses to ecosystem changes and are an excellent indicator of the overall health of an ecosystem. They play host to a number of bird and plant species of special interest to botanists and biologists.

### Harpers Ferry Water Gap

A water gap is a deep pass in a mountain ridge through which a stream or river flows (Harris et al., 1997). The water gap at Harpers Ferry is an extreme example due to the magnitude of the two rivers joining there. The Potomac River has cut its water gap through the Blue Ridge Mountains. At places this gap is rather wide. The gap through the Blue Ridge- Elk Ridge to the west and Short Hill- South Mountain to the east expose the repeated beds (due to faulting and folding) of the western limb of the Blue Ridge Anticlinorium (described above) (Patchen and Avary, 1986).

**Figure 5: High ground at Antietam National Battlefield. Strategic high ground areas in the battlefield played a major role in the outcome of conflicts during the Civil War. Present resource management concerns include erosion from such highlands in the attempt to preserve the historical landscape. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

**Figure 6: Low ground at Antietam National Battlefield. “Bloody Lane” was the scene of heavy casualties during the Battle at Antietam; another instance of geological-topographical features playing significant roles in history. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

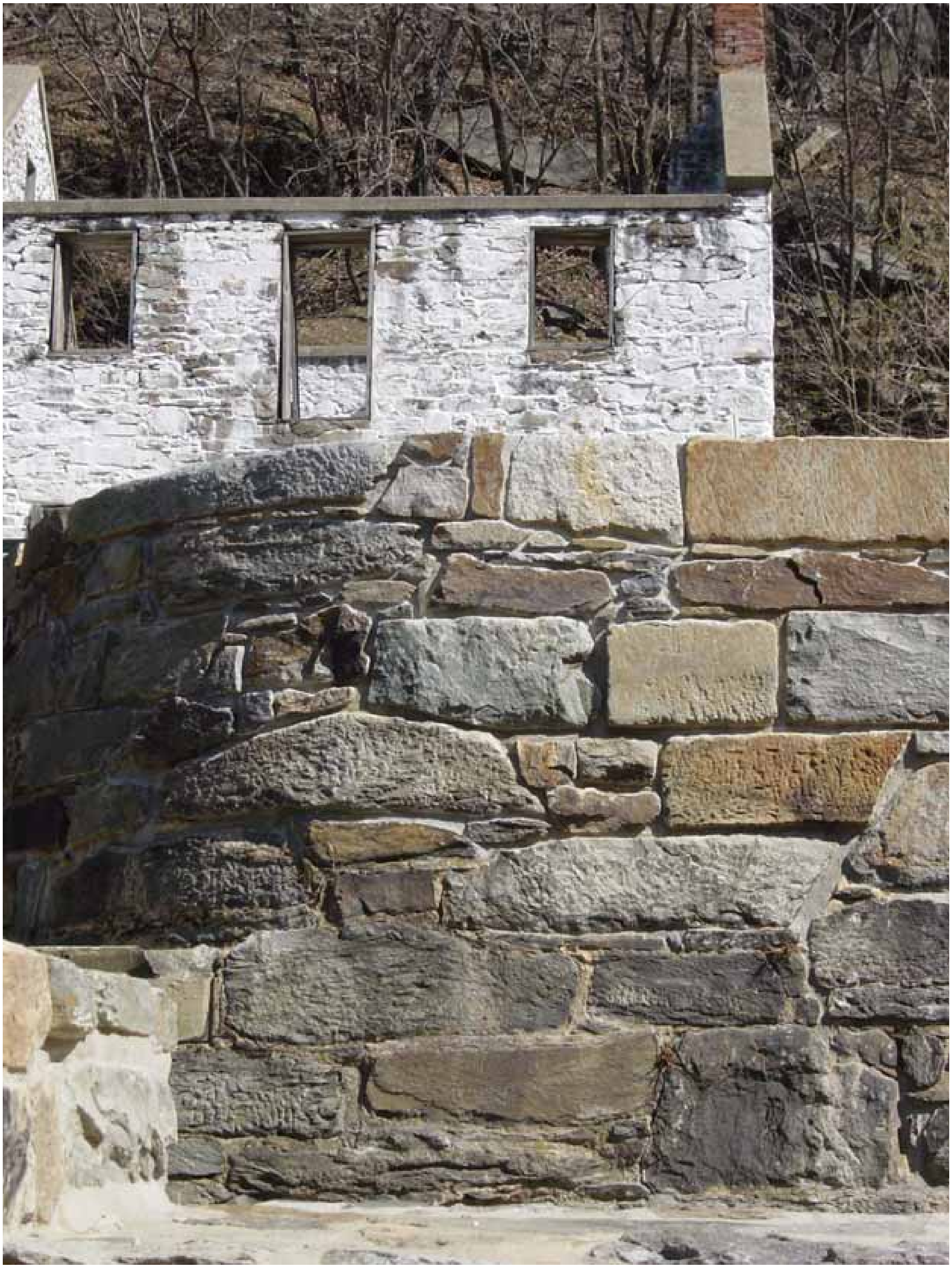

**Figure 7: Rock wall geology of Chesapeake & Ohio Canal, displaying fine examples of the different rock types including limestone, dolomite, and sandstone used in the construction of lock 33 of the Chesapeake & Ohio Canal. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

**Figure 8: Lock 30 of the Chesapeake & Ohio Canal. The Potomac River corridor is the site of more than just tourism in the National Park units. Many users including the railroad, utility companies, roads and highways, telecommunications lines and towers, tourists, local towns and residents all place demands on the resources available along the banks of the Potomac. The park provides a buffer of riparian habitat between the river and encroaching development. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

**Figure 9: View of Harpers Ferry. Harpers Ferry sits on the slopes above the meeting of the Potomac and Shenandoah Rivers. This dynamic setting is inherently subject to flooding, river bank erosion, and channel morphology changes. The steep slopes within and above the town are prone to rockfall, slumping and sliding. This presents unique management issues when dealing with the preservation of the historic structures of the national historical park. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

# Map Unit Properties

*This section provides a description for and identifies many characteristics of the map units that appear on the digital geologic maps of Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park. The table in this section is highly generalized and is provided for informational purposes only. Ground disturbing activities should not be permitted or denied on the basis of information contained in this table. More detailed unit descriptions can be found in the help files that accompany the digital geologic maps or by contacting the NPS Geologic Resources Division.*

The Central Appalachian area contains rocks varying in age from Quaternary sediments to Precambrian metamorphic gneisses. Because of the intense regional erosion by the Shenandoah, Potomac, and other large rivers and tributaries, these rocks are on striking display, indicative of the history of the area.

The oldest rocks of the area, are Proterozoic gneisses, metagranites, marbles, schists, and metarhyolites of the Catoctin and Swift Run Formations. The metasediments were deposited in an ancient sea basin skirting the eastern edge of the newly formed margin of the continent with the Iapetus Ocean. The Precambrian rocks form the basement upon which all other Appalachian rocks were deposited or intruded.

Early Cambrian Period sediments include the sands, silts, limes, and muds of the Mather Gorge Formation, the Ijamsville Phyllite, the Loudoun, Laurel, Sykesville, Weverton, Harpers, Antietam, Tomstown, Waynesboro, Araby, and Frederick Formations. Ordovician age rocks include the Conococheague, New Market, Chambersburg, and Stonehenge Limestones, the Juniata, and Martinsburg Formations, and several intrusive igneous units including the Georgetown Intrusive Suite and the Bear Island Granodiorite.

Rock units of Silurian age include the Hampshire, Foreknobs, Brallier, Magantango, Oriskany, Needmore, Helderberg, Willis Creek, Bloomsburg, Mckenzie and Rosehill Formations. Also of Silurian age are the Keyser, and Tonoloway Limestones and the Keefer Sandstone. The Purslane and Rockwell Formations are Mississippian in age.

Mesozoic age rocks include the Triassic Balls Bluff Siltstone and the Manassas Sandstone. Jurassic diabase dikes and sills intrude overlying rocks locally. The Cretaceous Potomac Formation includes loose sediments and abundant plant remains.

These rocks were uplifted, faulted and folded during several orogenies ultimately culminating in the Appalachian Mountains. Following each uplift, rapid erosion of the areas major rivers and tributaries resulted in thick deposits of sediments stretching the coastline further east in the Atlantic Coastal Plain physiographic province. Quaternary alluvium, colluvium, and terrace deposits manifest this erosion- sedimentation process.

The following three pages present a table view of the stratigraphic column and an itemized list of features per rock unit. This sheet includes several properties specific to each unit present in the stratigraphic column including: map symbol, name, description, resistance to erosion, suitability for development, hazards, potential paleontologic resources, cultural and mineral resources, potential karst issues, recreational use potential, and global significance.

## Map Unit Properties Table

| Age | Unit Name (Symbol) | Features and Description | Erosion Resistance | Suitability for Development | Hazards | Potential Paleontologic Resources | Potential Cultural Resources | Mineral Specimens | Potential for Karst Issues | Mineral Resources | Habitat | Recreation Potential | Global Significance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QUATERNARY-TERTIARY | Alluvium (Qa), Colluvium (Qc), Terraces (QTt) | Unconsolidated clay, silt, sand, and gravel underlying flood plains; cobbles and boulders on mountain slopes; sand, gravel, and boulders underlying flat benches and isolated hills; includes some strath terraces with no deposits | Low | No restrictions unless undercut on saturated slope; may be too permeable for waste facilities. | Slope processes such as slumping, sliding, creep | Pollen horizons | Artifacts, battle relics, (e.g., bullets) common locally | Cobbles from metamorphic crystalline basement rocks | None | Sand, gravel, pebbles, clay, river cobbles for building material | Riparian habitats along rivers; loose substrate for burrows | Trails, picnic and camping areas | Terrace deposits record downcutting of major rivers |
| CRETACEOUS | Potomac Formation (Kps) | Sand and clay with plant leaves; stems and trunks in the Coastal Plain Province | Low | High permeability may compromise waste facilities; otherwise, no restrictions to development | Slope processes such as slumping, sliding, creep | Plant leaves & stems; tree trunks | Charcoal, tools, implements from Native Americans | None | None | Sand, clay, pebbles | Riparian habitats along rivers; loose substrate for burrows | Trails, picnic and camping areas | Represents Cretaceous deposition in the region |
| JURASSIC | Diabase dikes and sills (Jd) | Black fine- to coarse- grained crystalline diabase in the Culpeper Basin of the Piedmont Province | High | No restrictions | Rockfalls possible on high angle slopes | None | None | Coarse grained crystalline diabase | None | None | None | None | Represents regional Jurassic time |
| TRIASSIC | Balls Bluff Siltstone- Lacustrine Member (TRbl); Balls Bluff Siltstone- Leesburg Member (TRbs); Manassas Sandstone- Poolsville Member (TRmp), Manassas Sandstone- Tuscarora Creek Member (TRmt), Manassas Sandstone- Reston Member (TRmr) | Red arkosic sandstone, pink variegated carbonate conglomerate, red arkosic sandstone, pink variegated carbonate conglomerate, tan quartz- pebble conglomerate | Moderate to high | Rich in carbonate; may be compromised by dissolution and friability, hummocky topography locally suggests sinkholes and caves | Sinkholes, caves, rockfalls where exposed on high angle slope | Crocodile footprints, small bird- like fossils; bones & teeth of phytosaur, coelacanth fossils; arthropods; lizard footprints, carnivorous dinosaur footprints, fossil sauropods, ornithischians prosauropods, & aetosaur | Chert pebbles may have supplied tool material | None | High; hummocky topography locally in carbonate units such as Leesburg Member of Balls Bluff Siltstone | Attractive building stones | Vugs, caves, sinkholes, etc. provide habitat for nesting birds, bats, and other burrowing animals | Climbing on sandstone units | |
| MISSISSIPPIAN | Purslane Formation(Mp)<br>Rockwell Formation (MDr) | Red and brown sandstone and pebble conglomerate, Green to gray sandstone, siltstone, and shale | Moderate to high (sandstone); Moderate (siltstone) | Unless highly fractured, no restrictions | Rockfall possible where units are exposed on high angle slope; mud- rich units may prove unstable on slopes | Brachiopods; rare conodonts | None | None | Low | None | None | Climbing on sandstone units | Contains Mississippian fossils and represents that time for the region |
| DEVONIAN | Lamprophyre dike (Dl), Hampshire Formation (Dh), Foreknobs Formation (Df), Brallier Formation (Db), Mahantango Formation (Dm), Marcellus Shale and Needmore Formations (Dmn), Oriskany Formation (Do), Helderberg Formation and Keyser Limestone (DShk) | Gray fine- grained quartz- plagioclase rock with biotite crystals; gray, green, and red sandstones; siltstones and shales; conglomeratic sandstones; medium- and coarse- grained sandstones; dark gray, fine- grained sandstones; light gray siltstones; calcite- rich shales and limestones; pebble conglomerates and cherty limestones | High (igneous rocks), Moderate | Units rich in carbonates may be compromised by dissolution and friability; unless highly fractured no restrictions documented | Karst features probable in carbonate units; rockfalls possible on high angle slopes; mud- rich units may be unstable on slopes | Brachiopods, clams, snails, cephalopods, trilobites (rare), conodonts | Chert nodules may have supplied tool material | Biotite crystals in lamprophyre dike | Moderate, in limestone rich units such as Keyser Limestone | None | Vugs in Keyser Limestone may provide nesting/bat habitat | None | Lamprophyre dike documents Devonian igneous intrusion |
| SILURIAN | Tonoloway Limestone (Stl), Willis Creek Formation (Sw), Bloomsburg Formation (Sb), McKenzie Formation (Sm), Keefer Sandstone (Sk), Rosehill Formation and Keefer Sandstone (Srk), Rosehill Formation (Sr), Tuscarora Quartzite (St) | Gray limestones, dolomites, calcareous shales, and thin sandstones; gray shales; claystones; red sandstones; siltstones; gray sandstones with Skolithus linearis; tan and red siltstones; red hematite sandstones and tan sandstones; white and gray quartzites; quartz pebble conglomerates | Moderate | Unless highly fractured, or rich in carbonates should be suitable for most development, no restrictions documented | Sinkholes, caves, rockfall where units are exposed on high angle slope | *Skolithus linearis*, brachiopods, snails, ostracodes, *Lepertidia*, eurytids (sea scorpions), bryozoans, corals, trilobites, stromatoporoids | Chert pebbles may have supplied tool material | Red hematite | High in Tonoloway Limestone | Attractive quartzite for building | Vugs, caves, sinkholes, etc. provide habitat for nesting birds, bats, and other burrowing animals | None | Units useful for correlation, esp. if rich in fossils |

| Age | Unit Name (Symbol) | Features and Description | Erosion Resistance | Suitability for Development | Hazards | Potential Paleontologic Resources | Potential Cultural Resources | Mineral Specimens | Potential for Karst Issues | Mineral Resources | Habitat | Recreation Potential | Global Significance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORDOVICIAN | Juniata Formation (Oj), Upper Member of Martinsburg Formation (Omu), Stickley Run Member of Martinsburg Formation (Oms), Chambersburg Limestone (Oc), New Market Limestone (On), Pinesburg Station Dolomite (Op), Kensington Tonalite (Ok) | Maroon sandstone and siltstone; brown and green shale, siltstone, and sandstone; gray shale and limestone; gray argillaceous, nodular limestone; gray thick- bedded limestone; gray, cherty, fractured dolomite; gray garnet- rich, muscovite- biotite tonalite | Moderate | Carbonate dissolution may render them too permeable for waste facility development; sinkholes and karst pose potential problems in carbonate rich units | Karst features probable in carbonate units, rockfall possible on high angle slopes, mud rich units may prove unstable on slopes | Snails, clams | Chert nodules may have supplied tool material | Garnets, muscovite (mica) | High in carbonate - limestone rich units | None | Vugs, caves, sinkholes, etc. provide habitat for nesting birds, bats, and other burrowing animals | None | Type locality for New Market Ls. and Martinsburg Fm. |
| | Georgetown Intrusive Suite- Biotite/ hornblende (Ogh), Georgetown Intrusive Suite- Biotite tonalite (Ogb), Georgetown Intrusive Suite- Quartz gabbro and quartz diorite (Ogg), Georgetown Intrusive Suite- Serpentine, soapstone, and talc schist (Ogv) | Gray foliated biotite- hornblende tonalite containing inclusions of mafic and metasedimentary rock; dark gray foliated quartz gabbro and quartz diorite; green foliated serpentinite, soapstone, and talc schist | High; Low (serpentinite, soapstone, talc schist) | High mica content may be unstable for foundations; otherwise, no restrictions | Rockfall possible where units are exposed on high angle slope | None | Soapstone and talc may have been used for sculpting | Soapstone | None | Soapstone and talc | None | None | Ordovician igneous activity |
| | Dalecarlia Intrusive Suite- Biotite monzogranite and granodiorite (Odm), Dalecarlia Intrusive Suite- Muscovite trondjemite (Odt), Rockdale Run Formation (Orr), Bear Island Granodiorite (Ob), Stonehenge Limestone (Os), Stoufferstown Member of Stonehenge Limestone (Oss), Quartz (Oq), Conococheague Limestone (OCc) | Gray foliated biotite monzogranite and granodiorite; light gray muscovite trondjemite, occurring as dikes, sheets and bodies; gray limestone interbedded with dolomite; light gray and white muscovite- biotite granodiorite and pegmatite; gray limestone; gray silty, laminated limestone with shale partings; massive bodies of white vein quartz; gray limestone interbedded with gray dolomite and sandstone | Moderate to high | Possible carbonate dissolution in Conococheague Limestone; high mica contents may be unstable for foundations, otherwise, no restrictions | Rockfall possible where units are exposed on high angle slope, karst features probable in carbonate rich units | Trilobites, conodonts, snails, brachiopods, cephalopods, echinosphaerites, bryozoans | None | Pegmatite minerals | High in Stonehenge and Conoco- cheague Limestones | Gold and other rare minerals associated with vein quartz and pegmatites | Vugs, caves, sinkholes, etc. provide habitat for nesting birds, bats, and other burrowing animals | Caving? | Ordovician igneous activity |
| CAMBRIAN | Conococheague Limestone- Big Spring Member (Ccb), Frederick Formation- Adamstown Member (Cfa), Frederick Formation- Rocky Springs Station Member (Cfr), Elbrook Limestone (Ce), Araby Formation (Car) | Dolomite and dolomitic sandstone; silty limestone and silty dolomite; dolomitic limestone; breccia of limestone clasts and sandstone; interbedded limestone and dolomite; gray and brown mottled sandy metasiltstone | Moderate | Sinkholes and karst pose potential problems in carbonate- rich units | Sinkholes, caves, rockfall where units are exposed on high angle slope | Trilobites, conodonts, stromatolites | Chert pebbles may have supplied tool material | None | High in carbonate- rich units | Attractive building stones, many used in Washington D.C. buildings and monuments | Vugs, caves, sinkholes, etc. provide habitat for nesting birds, bats, and other burrowing animals | Caving? | Famous marbles for monuments; Frederick Fm. type locality is nearby |
| | Waynesboro Formation- Chewsville Member (Cwac), Waynesboro Formation- Cavetown Member (Cwak), Waynesboro Formation- Red Run Member (Cwar) | Red siltstone and shale; gray limestone interbedded with dolomite; tan sandstone and green shale | Moderate | Mudstone- rich slopes may be unstable; possible limestone dissolution; otherwise, no restrictions | Shale units can be unstable on slopes; karst features, rockfall on high angle slopes | Lower Cambrian fossils rare | None | None | High in Cavetown Member of Waynesboro Fm. | None | Vugs in Cavetown Member may provide nesting/bat habitat | Caving? | |
| | Tomstown Formation (Ct), Tomstown Formation- Dargan Member (Ctd), Tomstown Formation- Benevola Member (Ctb), Tomstown Formation- Fort Duncan Member (Ctf), Tomstown Formation- Bolivar Heights Member (Ctbh) | Grey dolomite; gray limestone interbedded with dolomite; light gray dolomite; dark gray dolomite with bioturbation structures; dark gray limestone | Moderate | Cleavage along bedding planes in Tomstown Formation may be surfaces of weakness | Sinkholes, caves, rockfall where units are exposed on high angle slope | Lower Cambrian fossils rare | None | Sphalerite, calcite locally in vugs of Tomstown Formation | High | None | Vugs in Tomstown Fm. may provide nesting/bat habitat | None documented | Type locality for Tomstown Fm. |

| Age | Unit Name (Symbol) | Features and Description | Erosion Resistance | Suitability for Development | Hazards | Potential Paleontologic Resources | Potential Cultural Resources | Mineral Specimens | Potential for Karst Issues | Mineral Resources | Habitat | Recreation Potential | Global Significance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAMBRIAN | Carbonaceous phyllite (Ccp) , Antietam Formation (Ca), Harpers Formation (Ch), Weverton Formation (Cw), Sykesville Formation (Cs), Laurel Formation (Cl), Loudoun Formation- Conglomerate (Chilhowee Group Units) (Clc) | Dark gray lustrous graphitic phyllite; brown iron- rich sandstone; gray and green phyllitic metasiltstone; gray quartzite and dark metasiltstone and metagraywacke and pebble conglomerate; gray quartzofeldspathic matrix with fragments and bodies of metamorphosed sedimentary, volcanic, and igneous rocks; gray quartzofeldspathic matrix with fragments of meta-arenite and muscovite biotite schist; dark gray and blue variegated cobble and pebble conglomerate; clasts composed of vein quartz, quartzite, red jasper, greenstone, and gneiss | Moderate (sandstone), High (igneous rocks) | Bedding plane cleavages may be surfaces of weakness; intersecting joints in Weverton Fm. may compromise rock strength; large scale folds (Blue Ridge Anticlorium) create steep dip which be unstable if undercut; faults in Weverton and Loudoun Fms. are weak points; karst processes likely | Karst features probable in carbonate units; rockfall possible where unit is exposed on high angle slope, mud rich units may prove unstable on slopes | Molds, worm tubes brachiopods, trilobites, cephalons, in Antietam Fm.; burrows including *Skolithus* in Harpers Fm. | Harpers and Weverton Fms. make up several buildings in Harpers Ferry and have hand-carved steps leading up slope | Zircon, magnetite, ilmenite, and tourmaline in sedimentary rocks locally; red jasper in Loudoun Fm.; large quartz grains and magnetite in Weverton Fm.; large quartz pebbles in Antietam Fm. | Very high, responsible for sinkholes, caves, etc. | Attractive quartzite building material in Weverton Fm., and in Harpers Fm., Quartz veins in Antietam Fm. may have rare gold | Vugs, caves, sinkholes, etc. provide habitat for nesting birds, bats, and other burrowing animals | Climbing on sandstone units, caving | Type localities for Harpers, Antietam, Loudoun, Weverton Fms. |
| PRECAMBRIAN | Loudon Formation- Phyllite (CZlp), Ijamsville Phyllite- Phyllite (CZi), Ijamsville Phyllite- Greenstone (CZig), Ijamsville Phyllite- Metalimestone (CZil), Mather Gorge Formation- Metagraywacke (CZmg), Mather Gorge Formation-Migmatite (CZmm), Mather Gorge Formation- Phyllonite (CZmp), Mather Gorge Formation- Schist (CZms), Ultramafic rock (CZu), Amphibolite and ultramafic rock (CZa), Metagabbro and metapyroxenite CZg), Tuffaceous schist (CZt) | Gray, black, cream, and pink variegated phyllites, slates, and phyllonites with vein quartz; green schistose basaltic volcanic rock; gray metagraywackes interbedded with schist; mixture of former partial melt of dark gray quartzose schist (older paleosome) and light gray and white quartz plagioclase granitoid (younger leucosome); gray and green lustrous chlorite-sericite phyllonite; gray, green, and brown quartz- rich schist and mica gneiss interbedded with metagraywacke and calc- silicate rock; dark and light green serpentinite, soapstone, and talc schist; dark green and black amphibolite and ultramafic rock; dark metagabbro and metapyroxenite; hornblende- plagioclase- quartz-muscovite felsic tuffaceous schist | Moderate | Intersections of bedding and flow cleavages in phyllites may be points of weakness in phyllitic units | Micaceous units may be unstable on steep slopes; rockfall possible where on steep slopes | None | None | Zircon and tourmaline in sedimentary rocks locally; sericite & magnetite present in Loudoun Fm.; ultramafic rocks | None | None | None | Climbing possible | Type locality for Loudoun Fm. in Loudoun County, MD |
| | Catoctin Formation- Greenstone (Zc), Catoctin Formation- Phyllite and Sandstone (Zcs), Metarhyolite dike (Zrd), Metadiabase dikes (Zmd), Swift Run Formation- Marble (Zsm), Swift Run Formation- Phyllite and Schist (Zsp), Swift Run Formation- Metasandstone (Zsq) | Green metamorphosed basaltic lava flows; gray variegated vesicular and blebby phyllite and tan medium- grained sandstone; tan fine- grained felsite with feldspar crystals; green schistose metadiabase; pink and tan massive to schistose marble; tan sandy sericitic phyllite; tan medium- grained metasandstone with cobbles and pebbles of vein quartz | Moderate to high | Intersections of bedding and flow cleavages in phyllites may be points of weakness in phyllitic units | Rockfall possible where units are exposed on high angle slope | None | None | Zircon and tourmaline in sedimentary rocks locally; sericite common; epidote and actinolite in Catoctin Fm. | None documented | Local marble lenses, and attractive quartzite beds in Swift Run Fm., greenstone in Catoctin Fm. | None | None | Provide insight to Precambrian tectonics |
| | Biotite granite gneiss (Ybg), Leucocratic metagranite (Yg), Garnetiferous leucogratic metagranite (Ygt), Quartz plagioclase gneiss (Ygp), Hornblende monzonite gneiss (Yth), Garnet graphite paragneiss (Yp) | Light gray foliated granite gneiss with black specks of biotite; light- gray foliated metagranite; light gray foliated metagranite with garnet; white massive gneiss; tan to dark foliated gneiss with greenish black hornblende crystals; rust- colored schist with garnet crystals and flakes of graphite | High | Gneissic foliation and associated joints, cleavage, and fractures may be planes of weakness | Rockfall possible where units are exposed on high angle slope | None | None | Potash feldspar augen, clear albite crystals, rare garnets, zoisites | None documented | Rare graphite | None | Climbing possible | Oldest rocks in region; Precambrian tectonics |

# Geologic History

*This section highlights the map units (i.e., rocks and unconsolidated deposits) that occur in Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park and puts them in a geologic context in terms of the environment in which they were deposited and the timing of geologic events that created the present landscape.*

The recorded history of the Appalachian Mountains begins in the Proterozoic. In the mid- Proterozoic, during the Grenville orogeny, a supercontinent had formed which included most of the continental crust that existed during that time. This included the crust of North America and Africa. The sedimentation, deformation, plutonism (the intrusion of igneous rocks), and volcanism are manifested in the metamorphic gneisses in the core of the modern Blue Ridge Mountains (Harris et al., 1997). These rocks were deposited over a period of a 100 million years and are more than a billion years old, making them among the oldest rocks known from this region. They form a basement upon which all other rocks of the Appalachians were deposited (Figure 10) (Southworth et al., 2001).

The late Proterozoic, roughly 600 million years ago, brought a tensional, rifting tectonic setting to the area. The supercontinent broke up and a sea basin formed that eventually became the Iapetus Ocean. This basin collected many of the sediments that would eventually form the Appalachian Mountains. Some of the sediments were deposited as large submarine landslides and turbidity flows, and these preserve the dramatic features from their emplacement. These early sediments are exposed today on Catoctin Mountain, Short Hill- South Mountain, and Blue Ridge- Elk Ridge. Also in this tensional environment, flood basalts and other igneous rocks such as diabase and rhyolite added to the North American continent. These igneous rocks were intruded through cracks in the granitic gneisses of the Blue Ridge core and extruded onto the land surface during the break- up of the continental land mass (Southworth et al., 2001).

Associated with the shallow marine setting along the eastern continental margin during the Iapetus Ocean's duration, were large deposits of sands, silts, and muds in near shore, deltaic, barrier island and tidal flat areas. Some of these are represented by the Antietam Formation in Central Virginia (Schwab, 1970; Kauffman and Frey, 1979; Simpson, 1991). Also, huge masses of carbonate rocks represent a grand platform, thickening to the east, which persisted during the Cambrian and Ordovician Periods (545- 480 Ma). Somewhat later, 540, 470, and 360 million years ago, amphibolite, granodiorite and pegmatite, and lamprophyre, respectively, intruded the sedimentary rocks. Several episodes of mountain building and continental collision responsible for the Appalachian Mountains contributed to the heat and pressure that deformed and metamorphosed the entire pile of sediments, intrusives, and basalts into schists, gneisses, marbles, slates, and migmatites (Southworth et al., 2000).

The rocks were then extensively folded and faulted. This may have occurred during regional rifting that occurred about 200 million years ago. Given the available fault conduits, hot fluids moved upward, depositing quartz veins containing small amounts of gold. This was the source of the mining interest in the area, intermittently from 1867 until 1941 (Reed, Sigafoos, and Fisher, 1980).

From the Early Cambrian through the Early Ordovician time orogenic activity along the eastern margin of the continent began again. This involved the closing of the ocean, subduction of oceanic crust, the creation of volcanic arcs and the uplift of continental crust. In response to the overriding plate thrusting westward onto the continental margin of North America, the crust bowed downwards creating a deep basin that filled with mud and sand eroded from the highlands to the east (Harris et al., 1997). This so- called Appalachian basin was centered on what is now West Virginia. These infilling sediments covered the grand carbonate platform and are today represented by the shale of the Ordovician (450 Ma) Martinsburg Formation (Southworth et al., 2001).

During the Late Ordovician, the oceanic sediments of the shrinking Iapetus Ocean were thrust westward onto other deepwater sediments of the western Piedmont. This occurred along the Pleasant Grove fault. Sandstones, shales, siltstones, quartzites, and limestones were then deposited in the shallow marine to deltaic environment of the Appalachian basin. These rocks, now metamorphosed, currently underlie the Valley and Ridge province. The Piedmont metasediments record the transition from non- orogenic, passive margin sedimentation to extensive, syn- orogenic clastic sedimentation from the southeast during Ordovician time (Fisher, 1976).

Shallow marine to fluvial sedimentation continued for a period of about 200 My during the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods. This resulted in thick piles of sediments. The source of these sediments was the highlands that were rising to the east during the Taconian orogeny (Ordovician), and the Acadian orogeny (Devonian). The Taconic orogeny involved a volcanic arc – continent convergence. Oceanic crust and the volcanic arc were thrust onto the eastern edge of the North American continent. The Acadian orogeny continued the mountain building of the Taconic orogeny as the African continent approached North America (Harris et al., 1997).

Following the Acadian orogenic event, the proto-Atlantic Iapetus Ocean was completely destroyed during the Late Paleozoic as the North American continent collided with the African continent. This formed the Appalachian mountain belt. This mountain building episode is called the Alleghanian orogeny, the last major orogeny of the Appalachian evolution. The rocks were deformed by folds and faults to produce the Sugarloaf Mountain anticlinorium and the Frederick Valley synclinorium in the western Piedmont, and the Blue Ridge- South Mountain anticlinorium, and the numerous folds of the Valley and Ridge province (Southworth et al., 2001).

During this orogeny, rocks of the Great Valley, Blue Ridge, and Piedmont provinces were transported westward onto younger rocks of the Valley and Ridge along the North Mountain fault. The amount of compression was extreme. Estimates of 20- 50 percent shortening which translates into 125–350 km (75- 125 miles) of translation (Harris et al., 1997). Deformed rocks in the eastern Piedmont were also folded and faulted and existing thrust faults were reactivated as both strike slip and thrust faults during the Alleghanian orogenic events (Southworth et al., 2001).

Following the Alleghenian orogeny, during the Late Triassic, a period of rifting began as the deformed rocks of the joined continents began to break apart from about 230- 200 Ma. The supercontinent Pangaea was segmented into roughly the continents that persist today. This episode of rifting or crustal fracturing initiated the formation of the current Atlantic Ocean and caused many block- fault basins to develop with accompanying volcanism (Harris et al., 1997; Southworth et al., 2001). Large alluvial fans and streams carried debris shed from the uplifted Blue Ridge and Piedmont provinces. These were deposited as nonmarine shales and sandstones in fault- created troughs such as the Culpeper basin in the western Piedmont.

The large faults which formed the western boundaries of the basins provided an escarpment that was quickly covered with eroded debris. Igneous rocks intruded into the new strata as sub- horizontal sheets, or sills, and near- vertical dikes that extend beyond the basins into adjacent rocks. After these molten igneous rocks were emplaced at approximately 200 Ma, the region underwent a period of slow uplift and erosion. The uplift was in response to isostatic adjustments within the crust which forced the continental crust upwards and exposed it to erosion.

Thick deposits of unconsolidated gravel, sand, and silt were shed from the eroding mountains. These were deposited at the base of the mountains as alluvial fans and spread eastward becoming part of the Atlantic Coastal Plain (Duffy and Whittecar, 1991; Whittecar and Duffy, 2000; Southworth et al., 2001). The amount of material inferred from the now- exposed metamorphic rocks is immense. Many of the rocks exposed at the surface must have been at least 20 km (~10 miles) below the surface prior to regional uplift and erosion. The erosion continues today with the Potomac and Shenandoah Rivers and tributaries stripping the Coastal Plain deposits, lowering the mountains, and depositing alluvium on terraces. This fluvial erosion is largely responsible for creating the present landscape.

Since the breakup of Pangaea and the uplift of the Appalachian Mountains, the North American plate has continued to drift toward the west. The isostatic adjustments that uplifted the continent after the Alleghenian orogeny continued at a subdued rate throughout the Cenozoic Period (Harris et al., 1997).

The landscape and geomorphology of the Potomac River valley in particular is the result of erosion and deposition from about the mid- part of the Cenozoic Period to the present, or at least the last 5 million years. The distribution of flood plain alluvium and ancient fluvial terraces of the Potomac River and adjacent tributaries record the historical development of the entire drainage system. There is little evidence that the river migrated laterally across a broad, relatively flat region. It seems the river has cut downward overprinting its early course (Southworth et al., 2001).

The position, distribution, thickness, and elevation of terraces and the sediments deposited on them along the river vary by province and rock type. The elevations of terraces along the river show that the slope values of the ancient and modern river valley are similar which suggests that the terraces formed as the result of either eustatic sea level drop or uplift (Zen, 1997a and 1997b).

Though glaciers never reached the Maryland- West Virginia- Virginia area, the colder climates of the ice ages may have played a role in the river valley morphology. The landforms and deposits are probably late Tertiary to Quaternary in age when a wetter climate, sparse vegetation, and frozen ground caused increased precipitation to run into the ancestral river enhancing downcutting and erosion (Zen, 1997a and 1997b).

**Figure 10: Rock units at Harpers Ferry. Greenschist grade metamorphics exposed on a slope near Harpers Ferry National Historical Park. Metamorphic rocks are common within the Blue Ridge physiographic province. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).**

| Eon | Era | Period | Epoch | Ma | | Life Forms | N. American Tectonics |
|---|---|---|---|---|---|---|---|
| Phanerozoic (Phaneros = "evident"; zoic = "life") | Cenozoic | Quaternary | Recent, or Holocene | 0.8 | Age of Mammals | Modern man<br>Extinction of large mammals and birds | Cascade volcanoes |
| | | | Pleistocene | 1.8 | | | Worldwide glaciation |
| | | Tertiary | Pliocene | 5.3 | | Large carnivores | Uplift of Sierra Nevada |
| | | | Miocene | 23.8 | | Whales and apes | Linking of N. & S. America |
| | | | Oligocene | 33.7 | | | Basin-and-Range Extension |
| | | | Eocene | 55.5 | | Early primates | Laramide orogeny ends (West) |
| | | | Paleocene | 65 | | | |
| | Mesozoic | Cretaceous | | 145 | Age of Dinosaurs | **Mass extinctions**<br>Placental mammals<br>Early flowering plants | Laramide orogeny (West)<br>Sevier orogeny (West)<br>Nevadan orogeny (West) |
| | | Jurassic | | 213 | | First mammals<br>Flying reptiles | Elko orogeny (West)<br>Breakup of Pangea begins |
| | | Triassic | | 248 | | First dinosaurs | Sonoma orogeny (West) |
| | Paleozoic | Permian | | 286 | Age of Amphibians | **Mass extinctions**<br>Coal-forming forests diminish | Super continent Pangea intact<br>Ouachita orogeny (South)<br>Alleghenian (Appalachian) orogeny (East)<br>Ancestral Rocky Mts. (West) |
| | | Pennsylvanian | | 325 | | Coal-forming swamps<br>Sharks abundant<br>Variety of insects | |
| | | Mississippian | | 360 | | First amphibians<br>First reptiles | Antler orogeny (West) |
| | | Devonian | | 410 | Fishes | **Mass extinctions**<br>First forests (evergreens) | Acadian orogeny (East-NE) |
| | | Silurian | | 440 | | First land plants | |
| | | Ordovician | | 505 | Marine Invertebrates | **Mass extinctions**<br>First primitive fish<br>Trilobite maximum<br>Rise of corals | Taconic orogeny (NE) |
| | | Cambrian | | 544 | | Early shelled organisms | Avalonian orogeny (NE)<br>Extensive oceans cover most of N.America |
| Proterozoic ("Early life") | | Precambrian | | 2500 | | 1st multicelled organisms<br>Jellyfish fossil (670Ma) | Formation of early supercontinent<br>First iron deposits<br>Abundant carbonate rocks |
| Archean ("Ancient") | | | | ~3800 | | Early bacteria & algae | Oldest known Earth rocks (~3.93 billion years ago) |
| Hadean ("Beneath the Earth") | | | | 4600 | | Origin of life?<br>Formation of the Earth | Oldest moon rocks (4-4.6 billion years ago)<br>Earth's crust being formed |

**Figure 11: Geologic Time Scale adapted from the U.S. Geological Survey. Red lines indicate major unconformities between eras. Included are major events in life history and tectonic events occurring on the North American continent. Absolute ages shown are in millions of years. .**

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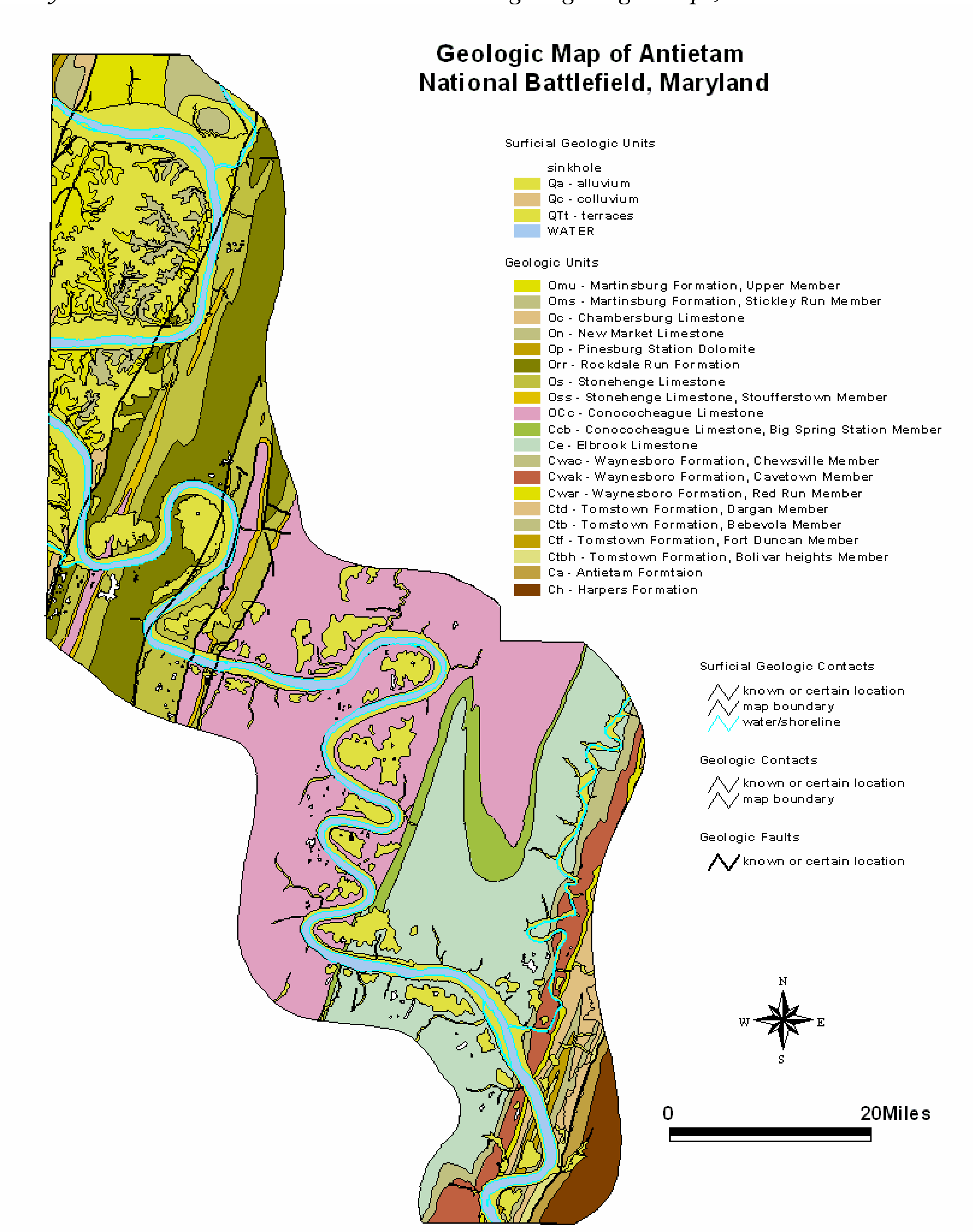
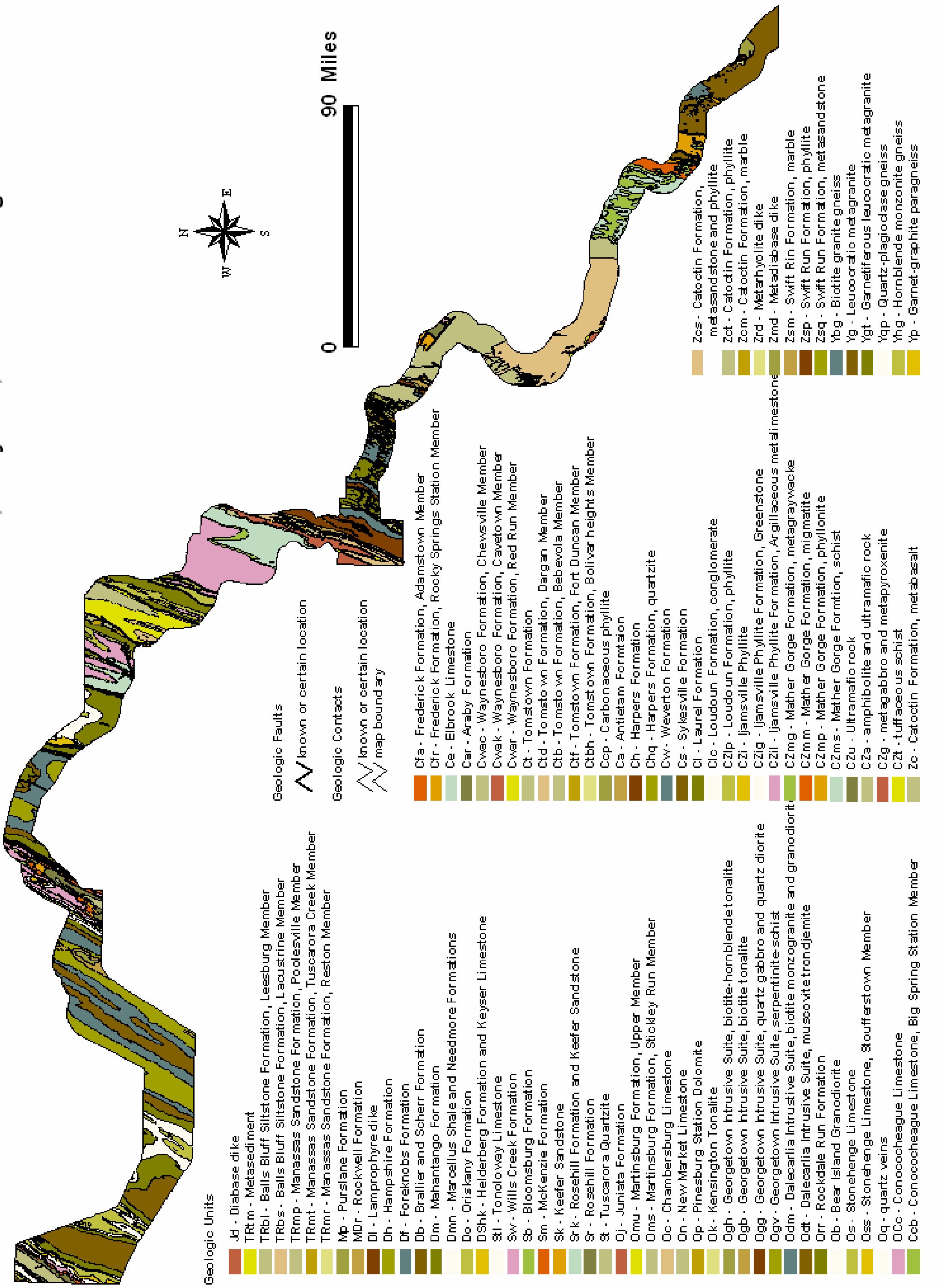
# Appendix A: Geologic Map Graphics

*These images provide previews or "snapshots" of the geologic maps for Antietam National Battlefield, Chesapeake & Ohio Canal National Historical Park, and Harpers Ferry National Historical Park. For detailed digital geologic maps, see included CD.*

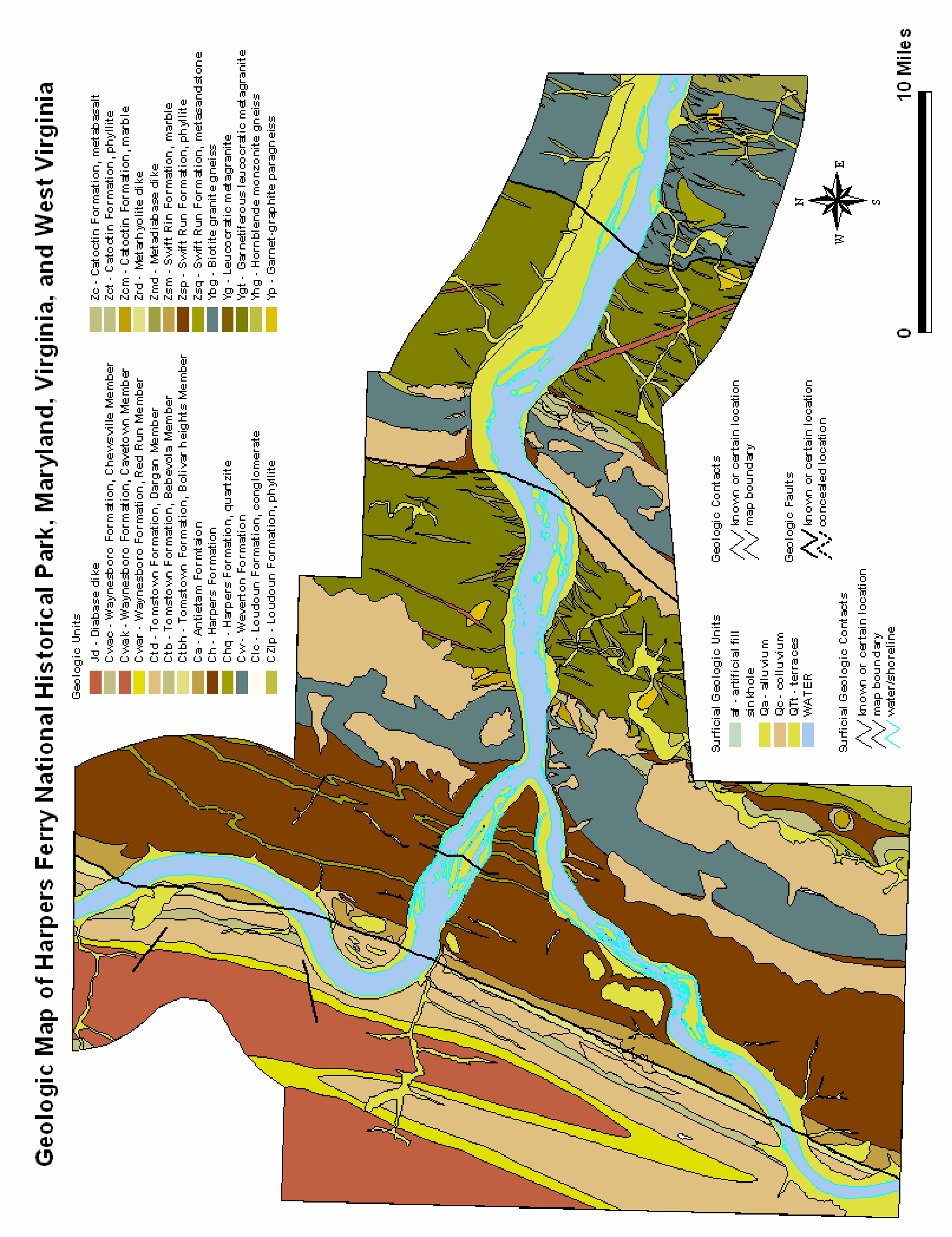



**The original map digitized by NPS staff to create this product was: Southworth, S., Brezinski, D.K., Orndorff, R.K., Chirico, P.G., and Lagueux, K., 2001, Geologic Map of Chesapeake and Ohio Canal National Historical Park and Vicinity, District of Columbia, Virginia, Maryland and West Virginia, USGS, OF-01-188A, 1:24,000 scale. For a detailed digital geologic map and cross sections, see included CD.**

## Geologic Map of Chesapeake & Ohio Canal National Historical Park, District of Columbia, Maryland, and West Virginia




**The original map digitized by NPS staff to create this product was: Southworth, Scott; Fingeret, Carrie; Weik, Thomas, 2000, Geologic map of the Potomac River gorge: Great Falls Park, Virginia, and part of the C & O Canal National Historical Park, Maryland, U.S. Geological Survey, OF-00-264, 1:10000 scale For a detailed digital geologic map and cross sections, see included CD.**




**The original map digitized by NPS staff to create this product was: Southworth, Scott; Brezinski, D.K.; Orndorff, R.C.; Logueux, K.M.; Chirico, P.G., 2000, Digital geologic map of the Harpers Ferry National Historic Park, U.S. Geological Survey, OF-00-297, 1:24000 scale. For a detailed digital geologic map and cross sections, see included CD.**

# Appendix B: Scoping Summary

*The following excerpts are from the GRE scoping meeting held for National Park Service Units in the National Capital Region. The scoping meeting occurred from April 30- May 2, 2001; therefore, the contact information and Web addresses referred to herein may be outdated. At the time of this meeting the GRE program was known as the Geologic Resources Inventory (GRI). Please contact the Geologic Resources Division for current information.*

### Executive Summary

Geologic Resources Inventory (GRI) workshops were held for National Park Service (NPS) Units in the National Capital Region (NCR) over April 30- May 2, 2001. The purpose was to view and discuss the park's geologic resources, to address the status of geologic mapping for compiling both paper and digital maps, and to assess resource management issues and needs. Cooperators from the NPS Geologic Resources Division (GRD), Natural Resources Information Division (NRID), individual NPS units in the region, and the United States Geological Survey (USGS) were present for the workshop.

This involved half- day field trips to view the geology of Catoctin Mountain Park, Harpers Ferry NHP, Prince William Forest Park and Great Falls Park, as well as another full- day scoping session to present overviews of the NPS Inventory and Monitoring (I&M) program, the GRD, and the on- going GRI. Round table discussions involving geologic issues for all parks in the National Capital Region included the status of geologic mapping efforts, interpretation, paleontologic resources, sources of available data, and action items generated from this meeting.

This summary contains a list of attendees for the scoping sessions

This summary also contains notes from C&O Canal staff on the meetings

Included is the PMIS project statement initially proposed by Pat Toops and Scott Southworth (note, the funding source needs to be updated to reflect the source of funding as NPS I&M and not NPS NRPP), see App. G

### Overview of Geologic Resource Evaluation

The NPS GRE has the following goals:

- to assemble a bibliography of associated geological resources for NPS units with significant natural resources ("GRBIB") to compile and evaluate a list of existing geologic maps for each unit,
- to conduct a scoping session for each park,
- to develop digital geologic map products, and
- to complete a geological report that synthesizes much of the existing geologic knowledge about each park.

It is stressed that the emphasis of the inventory is *not* to routinely initiate new geologic mapping projects, but to aggregate existing "baseline" information and identify where serious geologic data needs and issues exist in the National Park System. In cases where map coverage is nearly complete (ex. 4 of 5 quadrangles for Park "X") or maps simply do not exist, then funding may be available for geologic mapping.

After introductions by the participants, Tim Connors (NPS- GRD) presented overviews of the Geologic Resources Division, the NPS I&M Program, the status of the natural resource inventories, and the GRE in particular.

He also presented a demonstration of some of the main features of the digital geologic database for the Black Canyon of the Gunnison NP and Curecanti NRA in Colorado. This has become the prototype for the NPS digital geologic map model as it reproduces all aspects of a paper map (i.e. it incorporates the map notes, cross sections, legend etc.) with the added benefit of being geospatially referenced. It is displayed in ESRI ArcView shape files and features a built- in Microsoft Windows help file system to identify the map units. It can also display scanned JPG or GIF images of the geologic cross sections supplied with the map. Geologic cross section lines (ex. A- A') are subsequently digitized as a line coverage and are hyperlinks to the scanned images.

Joe Gregson further demonstrated the developing NPS Theme Manager for adding GIS coverage's into projects "on- the- fly". With this functional browser, numerous NPS themes can be added to an ArcView project with relative ease. Such themes might include geology, paleontology, hypsography (topographic contours), vegetation, soils, etc.

Pete Chirico (USGS- Reston, VA) demonstrated the digital geology of Harpers Ferry and also showed the group potential uses of a digital geologic coverage with his examples for Anacostia and Cumberland Island. The USGS also showed various digital products that they've developed already for Chesapeake and Ohio Canal NHP and Great Falls.

At the scoping session, individual Microsoft Word Documents of Geologic Bibliographies for each NCR park were distributed.

The sources for this compiled information are as follows:

- AGI (American Geological Institute) GeoRef
- USGS GeoIndex
- ProCite information taken from specific park libraries

These bibliographic compilations were validated by GRE staff to eliminate duplicate citations and typographical errors, as well as to check for applicability to the specific park. After validation, they become part of a Microsoft Access database parsed into columns based on park, author, year of publication, title, publisher, publication number, and a miscellaneous column for notes.

From the Access database, they are exported as Microsoft Word Documents for easier readability, and eventually turned into PDF documents.

### Geologic Mapping

After the bibliographies were assembled, a separate search was made for any existing surficial and bedrock geologic maps for the National Capital Region parks. The bounding coordinates for each map were noted and entered into a GIS to assemble an index geologic map. Separate coverage's were developed based on scales (*1:24,000, 1:100,000*, etc.) available for the specific park. Numerous geologic maps at varying scales and vintages cover the area. Index maps were distributed to each workshop participant during the scoping session.

The index of published geologic maps are a useful reference for the NCR. However, some of these maps are dated and are in need of refinement and in other places, there is no existing large- scale coverage available. The USGS began a project to map the Baltimore- Washington DC area at 1:100,000 scale and as a result it was brought to their attention that modern, large- scale geologic mapping for the NCR NPS areas would be beneficial to NPS resource management.

Because of this, the USGS developed a proposal to re-map the NCR at large scale (1:24,000 or greater) and to supply digital geologic databases to accompany this mapping. Scott Southworth (USGS- Reston, VA) is the project leader and main contact. The original PMIS (Project Management Information Systems) statement is available in Appendix C and on the NPS intranet (PMIS number 60900); of note is that portions of it need to be changed to reflect that the source of funding will be Inventory and Monitoring funds and NOT NRPP.

To better facilitate the geologic mapping, Scott Southworth would like to obtain better topographic coverage for each of the NCR units. Tammy Stidham knows that some of these coverages are already available and will supply them to Scott and the USGS. In general, anything in Washington DC proper has 1 meter topographic coverage and Prince George's county has 1:24,000 coverage.

Notes on individual parks within NCR

- *Rock Creek Park (ROCR)* has been mapped by the USGS at 1:24,000 scale. At the time of the mapping, they focused in on the structural geology. Scott would like to refine the mapping to 1:12,000 scale, and to revisit some of the previous mappers interpretations. Tammy Stidham says that a 1:200 topographic base is available. Additionally, the USGS would like to obtain the topographic contours, hydrography, roads, buildings and structures, and digital ortho quarter quadrangles for use in a base map. Tammy mentioned that soils data is available but that it is dated.

  Digital coverage exists and has been compiled for the entire area at 1:100,000 scale. Springs and many historic quarries (commodity unknown) are present; there may also be paleontological quarries too; USGS has historical maps for area; topographic coverage of 1 meter.

- *George Washington Memorial Parkway (Arlington House)* has immediate resource management issues pertaining to the geology of the cemetery, as there are problems with stability and sliding at the site, and the sooner a geology GIS is created, the more beneficial it is likely to be to the park. The park hopes that Scott Southworth and USGS scientists will be able to assist on this issue.

- *Antietam NB (ANTI)* is covered under the existing mapping for C & O canal. However, Scott would like an enhanced topographic base; Tammy says she can supply it. There are also karst issues here, as it relates to the hydrology and karst systems here.

- *Catoctin Mountain (CATO)* will be a bigger project, as there is an interesting surficial geologic story here. Base data is needed. Tammy says that at the time of the scoping meeting, there is not yet topographic data available, but hopefully will be available by the time Scott gets there to map. James Voigt is concerned about poor forest regeneration and wonders if it's tied to the geology. The park would like to relate topographic aspect and the DEMs to the geology as well. There were discussions of trying to investigate the tie of the purple fringed orchid habitat to underlying geology. The superintendent is concerned about potential geologic hazards that might be associated with climbing, as well as potential problems that may exist along Route 77 near Big Hunting Creek. Park staff would like to see better interpretive graphics pertaining to the geology to use in park brochures as well as at wayside exhibits in the park.

- *Chesapeake and Ohio Canal NHP (CHOH)* has a digital geologic strip map currently under review by the USGS; it's hoped that it will be completed by the end of this fiscal year (2001). The mapping was done at 1:24,000 scale, and is in ArcInfo format. It will be possible to take the strip map and enlarge the specific units of CHOH for ease in resource management.

Also included as part of the CHOH geologic database are Antietam NB and most of Monocacy. These can be improved if an enhanced topographic base is available. Sinkholes are an issue here and it's hoped that the geology can be used to predict them; Scott has been mapping them as he finds them. Numerous cave openings have already been located with GPS units. Four gold mines have hazards associated with the openings; park should contact the Abandoned Mineral Lands (AML) staff in Denver GRD (Dave Steensen or John Burghardt). The park is currently working with Pete Biggam (GRD Soil Scientist) on their soils maps.

They have some doqq's and would like to derive a vegetation map from the existing soils and geology since they're so low on the I & M Vegetation priority list. They have some color infrared for south area from the 1980s that might work. They'd like 1:1200 fly overs, but that isn't something being provided as part of this project. Only have a few stereo pairs. They really want to integrate and use the data. Scott says Allegheny County wants the geologic data to make their soils maps.

Additionally, see the individual synopsis coming from Maria Frias and the CHOH Resource Management staff below.

- *George Washington Memorial Parkway (GWMP)*: Melissa Kangas and Ann Brazinksi gave us comments during our site visit. There are seep issues from Great Falls to Key Bridge. Invertebrates are found in these seeps and need studied for relationship to geology. Other geologic interpretive possibilities include the Historic Quarries of soapstone near Key Bridge and the geology of Theodore Roosevelt Island. Man- driven shoreline changes are also of interest to the park in the tidal area. Geologic hazards exist along trails for climbers. There is likely a good interpretive story of Theodore Roosevelt Island in the seeps on the south parkway in coastal plain, some springs, and the James Smith spring is of historic interest. They incorporate the fall line into the Theodore Roosevelt Island story. The website for the digital geology of Great Falls is available at: http://geology.er.usgs.gov/eespteam/Greatfalls/INDEX.HTML

- *Harpers Ferry NHP (HAFE)* wants to find uses of their digital geologic map. There has been work done on rock slides on steep sided slopes from the University of West Virginia. Scott Southworth's team has produced the digital geology already, and it is available on- line at http://geology.er.usgs.gov/eespteam/Harpers/index.htm. They used a 5 foot contour to enhance the previously published paper map. It is GRD's understanding that the map is available in the HAFE-GIS and that the park is currently using the data for resource management.

- *Manassas (MANA)* was unrepresented at the scoping session, but Bruce says they're doing exotic weed mapping based on geology. We have high resolution topographic data for Prince William County. It's geologically covered in Scott's 100,000 scale map.

- *Monocacy (MONO)* is lumped with Antietam; should have topographic coverage soon. Have occasional flood problems.

- *National Capital East Parks (NACE);* prioritize the parks 1- 12:

  1. Ft. Washington (gypsum crystals, Paleontology, seeps)
  2. Piscataway (significant paleontology, seeps); located in Prince George's and Charles Counties
  3. Greenbelt Park
  4. Oxen Run Parkway in DC
  5. Fort Circle Parks in DC with exception of Forts Foote, Stanton, Mayhan
  6. Oxen Cove park
  7. Anacostia Kennelworth parks; separate but contiguous
  8. BW Parkway
  9. Suitland Parkway
  10. Shepherd Parkway
  11. Harmony Hall
  12. Frederick Douglass Home

- *Prince William Forest (PRWI)* has the Quantico quadrangle in paper format, however USGS Geologist Wright Horton has been out to the park and found some issues with miscorrelated volcanic units on the map along South Fork (they shouldn't be volcanics). There was a major reclamation project of the Cabin Branch Pyrite Mine back in 1995 and the rehabilitation of the area is continuing still; there are a few websites on the subject (EPA website at http://www.epa.gov/reg3wapd/nps/pdf/cabinbranch.pdf ; NPS website http://www2.nature.nps.gov/grd/distland/prwi_restoration. ) The park is preparing "The Geology Trail and Related Sites" as an interpretive trail to showcase some of the parks geology. There is also an abandoned gold mine in the northwest portion of the park with partially collapsed mine shafts at Independence Hill. Bob Mixon has worked on the geology of the Joplin quadrangle; Scott and Pete Chirico will check on the status of the open file report as well as bringing Wright Horton in on this project.

- *Wolf Trap Farm (WOTR)* has 1:24,000 scale topographic coverage

- *Other miscellaneous notes of interest*: slides associated with Fort Circle parks; DC has lots of subsurface data from when the Metro was put in; USGS has access to it; Metro Rail is tunneled below NPS area and may be causing a loss of water to NPS areas from what's disappearing below. ROCR, Anacostia and another too.

### Digital Geologic Map Coverage

The USGS will supply digital geology in ArcInfo format for all of the NCR parks. GRI staff will take this data and add the Windows help file and NPS theme manager capability to the digital geology and will supply to the region to distribute to each park in NCR.

#### Other Desired GIS Datasets for NCR

Soils: Pete Biggam (GRD Soil Scientist) supplied the following information in reference to soils for parks:

*National Capitol Parks - Central* is covered by the "District of Columbia" Soil Survey (State Soil Survey Area ID MD099). It has been mapped, and is currently being refined to match new imagery. An interim digital product is available to us via NRCS, but the "final certified" dataset most likely will not be available until FY03.

*National Capitol Parks - Eastern* is covered by portions of 3 soil survey areas; "District of Columbia" (MD099), "Charles County, Maryland" (MD017), and "Prince George's County, Maryland" (MD033). Both Charles County and Prince George's County are currently being updated, with Charles County scheduled to be available sometime in calendar year 2002, and Prince George's County sometime within calendar year 2003.

Paleontology: Greg McDonald (GRD Paleontologist) would like to see an encompassing, systematic Paleontological inventory for the NCR describing the known resources in all parks with suggestions on how to best manage these resources. In addition to the parks containing paleo resources in NACE, according to his current database, the following are considered "paleo parks" in the NCR:

- Chesapeake & Ohio Canal NHP
- George Washington Memorial Parkway
- Manassas NBP
- Prince William Forest Park
- Harpers Ferry NHP

### Geologic Report

A "stand- alone" encompassing report on each parks geology is a major focus of the GRI. As part of the USGS proposal to map the NCR, they will be summarizing the major geologic features of each park in a report to accompany their database. It was suggested hoped that after the individual reports are finished that a regional physiographic report will be completed for the entire NCR.

### Timelines

Appendix C lays out a specific timeline for how the parks will progress.

Also, at this point, Harpers Ferry is complete and now Scott's main priority is to complete C & O Canal, then perhaps Great Falls (with possible assistance from Barry Wood). C & O Canal still needs page size printable maps for the individual units though to make it complete.

For GRFA, Scott already has a write- up for both sides of the river ("Geology of the Potomac River Gorge"). George Washington Memorial Parkway and Rock Creek are also already in progress.

### CHOH staff notes on the scoping session

“The purpose of the scoping session is to provide an informal setting to review the status of existing geology projects, discuss how the geology inventory can be used by the parks (resource management, interpretation, education, etc.). This will also be a great opportunity to learn about our geologic resources, locations of hidden gold deposits, the inventory process, and to communicate special needs or products that could be helpful to us (e.g. special maps, etc.).”

The following is a compilation and thoughts collected during the Geology scoping session April 30- May2, 2001.

#### CHOH Interpretation

Scientific terminology should be distributed to park in layman’s terminology of information for use with public

Needs for the public: develop visitor use maps, publications, walks and programs and information for development of brochures etc.

#### CHOH Natural and Cultural Resource Applications

Environmental assessments, potential construction sites

Correlation of Geology (surficial and bedrock) with vegetation to predict location of plant types, etc

Sinkholes: can we find more sinkholes with data?

Gold mine: What to do with gold mine – Abandoned Mines program to be contacted

VEGETATION MAPPING:
Park requests development of an interim vegetation map product

Currently have some gross land use data from USGS 1999 NLCD National Land Cover Dataset (from 30m TM)

Potential to use 1983- 4 color IR for interim map

NCR collectively addressing vegetation mapping from a region wide request : Diane Pavek working with Rapid Assessment for Vegetation Mapping (Chris Lea); Mike Storey to petition for I&M buy in; I&M funds needed, ½ with ½ NCR Fee Demo. (Tammy Stidham following up with Mike Storey)

Locate quarries in relationship to locks and other stone historic structures.

Erosion issues and flooding of Potomac River – impact on resources

Issues

Geology project will have mapped specific geologic features, such as Devils Eyebrow?

How to use the data to manage resources: relationships among data, application development for park

Park staff need for instruction and understanding of data and appropriate use of data

Park understands that the strike and dip information was not mapped for park – too labor intensive

CHOH Park Management

Is large scale mapping possible 1:1200 from Geologic mapping program. Answer USGS: no

Goal: determining relationships between our resources

Workshop: NCR or select like parks – develop a workshop for interpretation with geologists and liaison go between and resources management to promote use of information for public at park.

What can WASO do for the park?

Potomac Gorge geology review: currently assessing geology of Potomac gorge and Mather Gorge – tie into POGO SCP Site Conservation Plan possible???

WASO GRD

Plan to have Geology Scoping Report completed by mid- May

Role is NPS75 I&M goal to inventory geologic resources

No funding for interpretation or interpretive products

2 WASO positions as liaisons between Interpretation, science and resources management

Developing GIS applications and Theme manager, one application per each of 12 GIS theme layer; GEO data to be prepared for park and installed into theme manager

3 year proposal with USGS: National Geologic Mapping Project Goals

Title: *Geologic Mapping – minimum data sets: NCR parks 1:24,000*

NCRO- N- 002.000

Scoping sessions with parks

Develop park specific bibliography: known references of park from PROCITE, USGS Geo- Index and AGI (American Geologic Institute) Geo- reference

Produce through USGS digital geologic map (delivered in Theme Manager format)

Prepare geologic reports per park and for the region

NCR? 11 parks mapped

Large scale 1:6000

Tailored to park products

Time frame: USGS plans to complete mapping for

CHOH by end of FY01

NPS training: data management training with theme applications: Soils, vegetation, geology, $H_2O$, etc

Current option for technical assistance: Contact Lindsey, Eastern Representative at USGS to broker and obtain technical assistance from USGS for what ever, including interpretation

Technical Assistance request can be made to the NRPC (?) for application development; not an NRPP request; to I&M program

Funding requests through the unified call

Geo- Scientists in the parks: GRD administers for in the park seasonal geo- scientist for projects such as developing interpretive products; contact in GRD is ?

Shortly after the scoping sessions, our office releases a "scoping summary" posted to a website as both documents and web pages. Some examples from Utah can be found at: http://www2.nature.nps.gov/grd/geology/gri/products/scope_summary/

**USGS**

Parks requested from USGS 50 copies for NCR parks Circular 1148, Forum on Geologic Mapping Applications in the Washington-Baltimore Urban Area

USGS interested in getting the information to the public but will rely on NPS to do this kind of work; not in current scope of work in above mentioned project.

USGS requests CHOH to GPS map perimeter of sink holes in park

USGS requests CAVE openings data from CHOH

National Geologic Mapping Project, led by Scott Southworth; products in GIS with a tabular usable database which will be reviewed by GRD

Anacostia project – historic and current hypsography mapped and compared; too cool.

Potomac Gorge geology review: currently assessing geology of Potomac gorge and Mather Gorge – tie into POGO SCP Site Conservation Plan possible???
Interpretation Vs Data:
USGS will provide the facts in understandable terminology plus data attributes. NPS to interpret data

Solicit Park and History Association to adopt and publish 'Rocks and the River' and other new publications

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# Antietam National Battlefield, Chesapeake and Ohio Canal National Historical Park, & Harpers Ferry National Historical Park

Geologic Resource Evaluation Report
NPS D-310, January 2005

## National Park Service

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## Natural Resource Stewardship and Science

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## Natural Resource Program Center

The Natural Resource Program Center consists of six divisions: Air Resources, Biological Resource Management, Environmental Quality, Geologic Resources, Natural Resource Information, and Water Resources Divisions. The Geologic Resources Division, in partnership with parks and others, works to protect, preserve, and understand the geologic resources of the National Park System and to protect park resources from the adverse affects of mineral development in and adjacent to parks. One of the functions of the Division, carried out in the Planning Evaluation and Permits Branch is the Geologic Resource Evaluation Program. This program develops digitized geologic maps, reports, and bibliographies for parks.

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Geologic Resource Evaluation Reports are published electronically on the World Wide Web, please see www2.nature.nps.gov/geology/inventory/gre_publications.htm. For a printed copy write to:

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Production of this geologic report was facilitated by the NPS Colorado Plateau Cooperative Ecosystem Studies Unit.

National Park Service
U.S. Department of the Interior

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